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ENGLISH AND AMERICAN RAILROADS COMPARED.

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SUPPLEMENTARY PAPER, READ MAY 5TH, 1886.*

WITH DISCUSSION.

Since the first part of my paper was prepared, I have passed nearly a year in England, observing closely the railroad question, especially the data from which I obtained the passenger and ton mileage—which is really the basis of the whole comparison. I again repeat my concluding remarks from page 75 of my paper: “He (the author) hopes that the railroads which are so largely interested in this question, will promptly replace his estimates by their official figures. Until this is done, he claims that these figures should be accepted as correct.”

The following Table, No. 42, which I had not time to finish before my paper was read, shows the expense of transporting one ton or one passenger one mile on some of the leading railroads of England and the United States, and also the comparative expense per train mile. To make the comparison more general, all the railroads of England and Wales, embracing 13 340 miles, are compared with all the roads of Massachusetts, embracing sixty-three companies, operating 2 852 miles,

* English and American Railroads Compared. By Edward Bates Dorsey, M. Am. Soc. C. E. Transactions, No. 318, Vol. XV, p. 1, January, 1886.

TABLE No. 42.
Showing the Cost per Train Mile and Ton, or Passenger Mile in Operating different Railroads in England and the United States.

NAME OF RAILROAD.	Total Length of Line Operated.	TOTAL MILEAGE.		Total Passenger and Ton Mileage.	AVERAGE LOAD OF TRAIN.		AVERAGE LENGTH OF HAUL.		AVERAGE COST OF OPERATING EXPENSES.	
		Passenger.	Ton.		Passenger.	Ton.	Passenger.	Ton.	Per Train Mile.	Transporting one Passenger, or one Ton, one Mile.
	Miles.						Miles.		Dollars.	Cents.
UNITED KINGDOM, 1883.										
Great Northern.....	768	286 512 050	502 873 520	789 485 570	35	61	10	53	0.687	1.22
North Eastern.....	1 534	350 184 052	1 159 091 280	1 518 875 332	37	78	9	29	0.677	1.10
Midland.....	1 381	432 151 874	1 222 309 920	1 654 461 794	33	61	12	48	0.563	1.12
London and North Western.....	1 783	745 745 134	1 511 779 440	2 257 528 574	39	78	12	42	0.555	1.11
Great Western.....	2 268	642 025 920	1 043 489 200	1 584 515 120	45	65	12	43	0.600	1.09
Great Eastern.....	1 049	386 454 286	369 094 320	755 548 606	45	65	5	52	0.630	1.15
London and South Western.....	721	406 375 606	216 649 920	623 025 526	51	71	9	59	0.716	1.38
London, Chatham and Dover.....	160	136 517 102	69 534 960	256 452 062	62	89	5	28	0.828	1.14
Eastonlian.....	877	198 718 818	400 718 818	651 862 938	37	69	10	30	0.636	1.16
North British.....	1 068	193 725 240	396 243 150	589 969 460	39	71	8	39	0.570	1.12
London, Brighton and South Coast.....	403	369 993 492	130 318 080	500 311 572	57	91	6	51	0.561	1.05
1884.—All the Railroads of England and Wales (average cost per mile, £49 288).....	13 340	5 199 240 104	.....	12 872 762 744	43	72	8	35	0.540	1.14
UNITED STATES, 1884.										
Boston and Lowell.....	550	61 343 056	59 427 991	120 771 047	43	97	14	40	1.083	1.72
Boston and Maine.....	204	89 587 566	44 937 544	134 525 110	69	83	13	47	1.137	1.55
Boston and Providence.....	68	55 200 708	21 814 483	77 015 191	76	89	10	30	1.399	1.77
Old Colony.....	468	116 745 901	57 899 872	174 645 773	71	72	15	36	1.212	1.68
New York, New Haven and Hartford.....	265	206 677 775	125 743 803	332 421 578	87	86	25	58	1.261	1.45
New York, Lake Erie and Western.....	1 029	169 599 245	1 794 946 519	1 964 545 764	45	239	19	162	0.745	0.62
N. Y. Cent. and Hudson River Railroad.....	993	387 329 886	1 790 087 115	2 357 919 001	60	196	69	193	1.085	0.74
Penn.-Railroad, Penn. Railroad Div.....	1 471	244 710 876	2 995 892 567	3 241 633 443	42	205	21	134	0.845	0.53
All the Railroads of Massachusetts (average cost per mile, \$69 281).....	2 852	1 007 156 376	1 229 368 472	2 236 504 848	67	110	15	60	1.173	1.38

averaging less than fifty miles per road to each company. It is evident that these small companies are operated at much greater expense, in proportion to their business, than the larger ones, as they cannot afford to hire such efficient management, or buy their supplies on such favorable terms as the larger companies, who make their purchases in very large quantities.

EXPLANATION OF TABLES.

In all cases the aggregate daily train mileage was obtained by assuming that the reported annual revenue train mileage was made in 315 working days; thus divide total annual revenue freight and passenger train miles by 315; then divide this quotient by the length of line operated.

In all cases the revenue mileage only has been counted, the working trains and switching mileage being excluded.

Except in the case of the New York Central and Hudson River Railroad, all canal, dock and steamboat expenditures have been excluded.

Mr. T. Russell Crampton, M. Inst. C. E., the celebrated English engine-builder, in a recent paper before the French Society of Engineers (see *London Engineer* of this year, page 354), estimated the average cost on six of the largest English railroads of repairs and renewals of locomotives at over 3d. per train mile; this is somewhat higher than my figures from the official reports of the companies.

No reports or returns have been received for 1885 from the English railroads or the Board of Trade.

The cost has been taken from the reports of the respective companies, or from the Reports of the Board of Trade of the United Kingdom.

Except when otherwise stated, taxes and duties have been included in the operating expenses.

I will repeat again, that no returns are made in England of the ton or passenger mileage, nor is there any attempt made to separate the cost of the freight or passenger traffic; consequently it has been necessary for comparison to add them together.

My plan for estimating the ton and passenger mileage was fully described on page 16, volume XV of the Transactions of this Society.

TABLE No. 43.

Showing the Average Cost of Transporting One Ton or One Passenger
One Mile on the Boston and Albany Railroad for the Last 18
Years.

Year.	Cents.	Year.	Cents.
1868.....	.0202	1877.....	.0088
1869.....	.0188	1878.....	.0083
1870.....	.0174	1879.....	.0071
1871.....	.0178	1880.....	.0087
1872.....	.0171	1881.....	.0083
1873.....	.0172	1882.....	.0083
1874.....	.0122	1883.....	.0090
1875.....	.0111	1884.....	.0081
1876.....	.0096	1885.....	.0072

By inspecting Table No. 42, it appears that the cost of transporting one ton one mile in England and Wales is about the same as transporting one passenger the same distance; this is shown in the last column under the head, "Cost of transporting one passenger, or one ton, one mile." This cost is very uniform on all the English railroads, notwithstanding the great variation in the proportion of total ton and passenger mileage, running from one passenger to three tons on the Midland and North Eastern Railways, costing 1.12 and 1.10 cents respectively, to three passengers to one ton on the London, Brighton and South Coast, and London, Chatham and Dover Railways, which cost 1.05 and 1.14 cents respectively.

This result is the natural consequence of the small average load on the freight trains, which resemble too closely for economy the passenger trains in speed, load and cost.

The average cost in 1884 of the train mile on all the railroads of England and Wales was \$0.64. On all the railroads of Massachusetts it was \$1.17, or nearly double, while the average train load is more than fifty per cent. larger in passengers and tons on the Massachusetts railroads.

The average cost in 1884 of transporting one passenger, or one ton, one mile on the English and Welsh railroads, was \$0.0114; on the railroads of Massachusetts it was \$0.0138, or 21 per cent. more. This is the actual

cost: no allowance has been made for the difference in cost of labor, materials and fuel. The pay of the engine-drivers and firemen in Massachusetts is more than double what it is in England and Wales. The price of fuel is fully three times as much. All wages will probably average 50 per cent. more, and all materials, except ties (sleepers) and lumber, are higher.

It is evident that if proper reductions are made for the difference in the cost of fuel, labor and materials in the two countries, the American railroads are operated much more economically than those of the United Kingdom, otherwise it will have to be admitted that American labor, at nearly double the price, is as cheap as English at about half the price. Either the American railroad management is more economical, or the American labor is more efficient.

If the American rolling stock is not better than the English, why have the Midland and other English railroads adopted so extensively the bogie-truck? And why has it been adopted so thoroughly in Canada, where all the railroads were built by English capital, and mostly by English engineers? Many roads were equipped at first with English-built rolling stock, which was afterwards changed to the American type?

It is instructive to compare the progress made in railroad traffic and its economics within the past thirty years. The able work of Messrs. Alexander L. Holley and Zerah Colburn* gives very reliable data for the years 1855 and 1856. In the following comparisons all the figures given for these years have been taken from their work, except those relating to the Pennsylvania Railroad. The figures for 1884 for English railroads have been taken from the Railway Returns of the Board of Trade, and for the American railroads from the Reports of the Railroad Commissioners of New York and Massachusetts.

*Strange as it may seem, it is only within the last few days that I have seen, for the first time, this book. At the time it was published and for many years afterward, I was engineering near the top of the Andes in South America, far removed from book-stores and libraries. Messrs. Holley and Colburn used the same plan that I did for estimating the ton mileage of the English railroads.

TABLE No. 44.

Comparison of Railroad Traffic in England and the United States in the Years 1855 or 1856 and 1884.

	1855 or 1856.	1884.
Cost per train mile:		
All railroads in England.....	<i>a</i> \$0.68	<i>l a</i> \$0.61
London and North Western.....	<i>a</i> 0.79	<i>a</i> 0.63
All railroads in New York.....	<i>a</i> 1.00	<i>b</i> 1.01
All railroads in Massachusetts.....	<i>a</i> 1.05	<i>b</i> 1.17
Pennsylvania Railroad.....	<i>h</i> 1.39	<i>h</i> 0.84
Cost of transporting one ton or one passenger one mile:		
All railroads of England.....	<i>a</i> 0.0115	<i>a</i> 0.0115
All railroads in New York.....	<i>a</i> 0.0160	<i>a</i> 0.0078
Pennsylvania Railroad.....	<i>h</i> 0.0231	<i>h</i> 0.0054
Average train load—passengers:		
All railroads of England.....	46	43
All railroads of New York.....	73	51
Pennsylvania Railroad.....	<i>h</i> 57	<i>h</i> 42
Average train load—tons:		
All railroads of England.....	55	72
All railroads of New York.....	71	183
Pennsylvania Railroad.....	<i>h</i> 61	<i>h</i> 205
Average charge per ton per mile:		
All railroads of England.....	<i>c</i> \$0.0275	<i>c</i> \$0.0200
All railroads of New York.....	<i>f</i> 0.0250	0.0083
Pennsylvania Railroad.....	<i>h k</i> 0.0375	<i>h</i> 0.0074
Average charge per passenger per mile:		
All railroads of England.....	0.0252	<i>d</i> 0.0209
All railroads of New York.....	0.0198	<i>f</i> 0.0208
Pennsylvania Railroad.....	<i>h</i> 0.0325	<i>h</i> 0.0242

a—Exclusive of taxes and duties.

b—Inclusive of taxes and duties.

c—Messrs. Holley and Colburn estimate the average charge for all kinds of freight in 1855 was \$0.0275 per ton of 2 000 pounds. My estimate in 1884 is \$0.0200 per ton of 2 240 pounds. This, probably, is one-fourth too low.

d—Including first, second and third-class ordinary and season tickets. Without the season tickets the average is estimated at \$0.0233.

f—For 1856, from the report of the State Engineer.

h—For 1856 and 1884, from reports of the Pennsylvania Railroad Company.

k—Exclusive of State tolls.

l—Including taxes and duties, \$0.64.

From the preceding table it appears that from 1855 to 1884, thirty years, the railroads of England have reduced their expenses per train mile 10 per cent., and have decreased their train load in passengers 7 per cent., and increased their train load in freight 31 per cent.

The cost of transporting one passenger, or one ton, one mile has remained practically the same, being in 1855, 1.15 cents, and in 1884, 1.13 cents.

The average freight charge in 1855, per ton of 2 000 pounds, was 2.75 cents; in 1884, was 2 cents per ton of 2 240 pounds. (This is the price I estimate; probably 2.5 cents would be more correct.) The average charge or fare per passenger per mile in 1855 was 2.52 cents; in 1884 it was 2.09 cents. This last includes all three classes, and ordinary and season tickets; without including season tickets, the average fare for all classes I estimate at 2.33 cents per mile.

In 1855 the average cost per train mile on all the railroads of New York was \$1; in 1884 it was \$1.01, an increase of one per cent. The train load in 1855 averaged 73 passengers; in 1884 the average was 51, a decrease of 30 per cent; while the freight train load had increased from an average of 71 tons in 1855 to 183 tons in 1884, a gain of 159 per cent. The average cost of moving one ton, or one passenger, one mile in 1855 was 1.60 cents; in 1884 it was .78 cents, a decrease of 51 per cent.

The Pennsylvania Railroad in 1856 charged per mile per passenger \$.0325; in 1884, \$.0242, showing a reduction of one-fourth. In 1856 the freight charge per ton per mile (exclusive of State tolls) was \$.0375; in 1884 it was \$.0074, a reduction of 80 per cent. In the same time the cost of transporting one passenger, or one ton, one mile decreased from \$.0231 to \$.0053, or 76 per cent.

On the American railroads much greater saving has been made in the freight than in the passenger traffic.

The English railroads, in economical workings and appliances, have apparently remained stationary during the last thirty years, while the American roads have improved so as to reduce the operating expenses more than one-half. On freight alone some roads have reduced their expenses and charges 80 per cent.

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In my previous paper the comparisons were confined to the railroads in the Middle or Eastern States. In this paper, with three exceptions, I will include in the comparisons the railroads in the Western and Southern States. These roads may be said to represent the true type of American railroad practice—they were cheaply constructed, and have been or are gradually being perfected, mostly from the earnings, while being operated. They are in the transition stage. Many bridges, buildings, etc., of wood, have been or are being replaced with iron or other durable material; iron rails with steel rails, etc. Until these changes are completed, the maintenance of way and operating expenses must necessarily appear large.

The Louisville and Nashville system embraces 2 065 miles of road. Average total cost per mile \$43 004, being about the average capital increase per mile of the English roads in the last fifteen years, thus:

	1870.	1884.
Average paid up capital per mile of all the railroads of the United Kingdom.....	£34 106	£42 486
Increase in fifteen years.....		8 380

The reported increase of rolling stock will only account for about £1 000 of this increased capital.

A careful inspection of Table No. 45 will show the following results for work actually done, *i. e.*, the cost of transporting 1 ton or 1 passenger 1 mile on our well-constructed roads, such as the New York Central and Hudson River, Pennsylvania, Chicago, Rock Island and Pacific, Louisville and Nashville, main stem, etc., the cost compared with the English roads is about one-half for maintenance of way, repairs and renewals of locomotives and motive power, and from half to three-quarters for total operating expenses.

On the roads of low cost and inferior construction, with few exceptions, the average cost of these items for 1885 was less than on the English roads—varying from one-half to seven-eighths.

For comparison, let us select from Table No. 45 the London and North Western Railway, and the Pennsylvania Railroad Division of the Pennsylvania Railroad. Each of these may truly be said to be the most perfect and extensive of their respective types.



Comparing the Cost of Maintenance of Way, Repairs and Renewals of Locomotives, Motive Power, and Total Operating Expenses.

NAME OF RAILROAD.	YEAR.	Average Length of Line Operated.	Aggregate Daily Trains Over Entire Line.	Average Cost per Mile.	AVERAGE LOAD OF TRAIN.			TOTAL COST OF MAINTENANCE OF WAY.		TOTAL COST OF REPAIRS AND RENEWALS OF LOCOMOTIVES.		TOTAL COST OF MOTIVE POWER.		TOTAL COST OF OPERATING EXPENSES.	
					Tons.	Passen- gers.	Tons and Passen- gers.	Per Train Mile.	Per 1 Ton or 1 Pas- senger Moved 1 Mile.	Per Train Mile.	Per 1 Ton or 1 Pas- senger Moved 1 Mile.	Per Train Mile.	Per 1 Ton or 1 Pas- senger Moved 1 Mile.	Per Train Mile.	Per 1 Ton or 1 Pas- senger Moved 1 Mile.
UNITED KINGDOM. £ = \$4.80. d = 2 cents.		Miles.						Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
Caledonian.....	1882 1883 1884	..... 877 878	..... 43 45	..... ..... .....	69 64	37 35	55 51	10.46 9.54 10.08	......174 .198	..... 5.06 5.22	......092 .102	15.26 15.92 16.26	......290 .302	62.40 63.64 60.26	..... 1.16 1.18
Great Eastern.....	1882 1883 1884	..... 1 049 1 038	..... 42 43	..... ..... .....	69 68	45 46	55 55	10.48 10.30 9.96	......188 .180	..... 5.30 5.06	......096 .092	17.32 17.88 17.12	......325 .311	64.42 63.04 61.24	..... 1.15 1.11
Great Northern.....	1882 1883 1884	..... 768 785	..... 68 69	..... ..... .....	61 60	35 34	48 47	9.64 9.50 9.20	......198 .196	..... 4.00 4.02	......083 .086	15.20 15.50 15.24	......322 .324	59.68 58.72 56.24	..... 1.22 1.20
Great Western.....	1882 1883 1884	..... 2 268 2 301	..... 42 42	..... ..... .....	65 64	45 44	55 54	14.30 14.22 13.80	......259 .255	..... 5.80.....	......105	15.14 15.26 15.38	......277 .285	59.92 60.04 59.34	..... 1.09 1.10
Great Southern and Western of Ireland...	1882 1883 1884	..... 478 496	..... 19 19	..... ..... .....	74 73	40 37	54 52	15.48 17.28 16.26	......320 .313	..... 6.00 5.96	......111 .115	18.66 18.62 18.18	......345 .350	69.40 68.94 67.30	..... 1.28 1.30
Lancashire and Yorkshire.....	1882 1883 1884	..... 494 496	..... 84 88	..... ..... .....	99 96	42 41	66 64	12.56 12.78 12.46	......194 .195	..... ..... .....	..... ..... .....	19.26 17.52 16.20	......267 .253	77.32 75.12 71.06	..... 1.14 1.11
London and North Western.....	1882 1883 1884	..... 1 793 1 811	..... 68 68	..... ..... .....	78 78	39 38	59 58	12.40 11.90 12.14	......202 .209	..... 4.60 4.78	......078 .082	15.10 15.40 15.72	......261 .271	66.54 65.52 65.66	..... 1.11 1.13
London and South Western.....	1882 1883 1884	..... 721 722	..... 49 49	..... ..... .....	71 69	51 51	56 56	13.60 12.78 13.06	......228 .233	..... 5.42 5.42	......097 .097	16.90 16.66 19.38	......298 .346	73.28 71.58 71.46	..... 1.28 1.27
London, Brighton and South Coast.....	1882 1883 1884	..... 403 417	..... 63 62	..... ..... .....	91 83	56 55	63 61	9.82 9.96 9.80	......188 .161	..... 4.24 4.48	......067 .073	18.06 18.20 17.94	......289 .294	66.52 66.08 63.70	..... 1.05 1.05
Manchester, Sheffield and Lincolnshire...	1882 1883 1884	..... 314 316	..... 66 69	..... ..... .....	77 75	35 34	62 60	9.26 8.92 8.80	......160 .147	..... ..... .....	..... ..... .....	14.36 14.90 14.26	......248 .238	66.18 65.48 65.02	..... 1.06 1.08
Midland.....	1882 1883 1884	..... 1 381 1 388	..... 76 76	..... ..... .....	61 61	33 33	59 50	10.18 9.50 8.96	......190 .180	..... 5.24 5.06	......105 .101	14.94 15.50 15.34	......310 .301	56.18 56.30 56.52	..... 1.12 1.13
North Eastern.....	1882 1883 1884	..... 1 534 1 534	..... 51 49	..... ..... .....	78 76	37 35	62 59	12.78 12.36 12.38	......199 .210	..... 7.84 8.34	......126 .141	20.60 21.24 21.50	......343 .364	69.14 67.74 67.78	..... 1.10 1.15
South Eastern.....	1882 1883 1884	..... 370 369	..... 55 59	..... ..... .....	85 82	66 62	71 66	11.08 10.78 9.94	......182 .151	..... 3.88 3.92	......053 .060	17.54 18.02 17.22	......255 .261	74.44 74.74 70.58	..... 1.05 1.07
All the Railroads of the United Kingdom.	1882 1883 1884	18 457 18 681 18 864	..... 46 46	£41 605 42 417 42 486	73 71	43 42	57 55	12.28 12.02 11.64	......211 .211	..... ..... .....	..... ..... .....	16.42 16.64 16.70	......291 .304	64.94 64.34 63.18	..... 1.13 1.15
All the Railroads of England and Wales ..	1882 1883 1884	..... 13 215 13 340	..... 54 54	..... 49 258 49 854	73 72	44 43	57 56	12.12 11.74 11.44	......206 .204	..... ..... .....	..... ..... .....	16.74 16.96 17.04	......300 .304	65.68 64.84 63.96	..... 1.14 1.14
UNITED STATES.															
Pennsylvania Railroad Division.....	1883 1884 1885	1 314 1 471 1 518	52 45 46	..... ..... .....	189 205 210	45 42 45	152 160 167	17.6 16.4 13.2	.116 .103 .080	7.1 7. 6.2	.047 .044 .037	24.5 23.8 22.2	.161 .148 .133	86. 84.5 78.2	.56 .53 .41
New York Central and Hudson River.....	1883 1884 1885	..... 993 993	..... 53 56	..... ..... .....	205 196 195	71 60 70	160 147 150	21.7 18.8 15.1	.134 .128 .100	6.8 5.2 4.9	.042 .035 .033	34.3 26.6 24.8	.214 .180 .165	123.2 108.5 92.8	.77 .74 .63
Louisville and Nashville System, Main Stem.....	1883 1884 1885	185 185 185	21 23 21	\$85 405 86 373 86 804	149 145 149	40 59 58	109 112 114	13.15 10.46 10.96	.121 .093 .096	4.51 4.64 4.13	.041 .041 .036	20.60 20.57 18.67	.190 .184 .164	85.31 85.39 81.58	.783 .762 .716
Nashville and Decatur.....	1883 1884	119 119	15 15	37 198 37 420	153 161	39 49	116 125	17.48 13.50	.151	4.57.....	.039	20.47.....	.176	103.94.....	.896

Lancashire and Yorkshire.....	1882	.....	.....	.....	.....	.....	12.56	.....	.....	.....	19.26	.....	77.52	.....
	1883	494	84	.....	99	42	66	12.78	.194	.....	17.52	.267	75.12	1.14
	1884	496	88	.....	96	41	64	12.46	.195	.....	16.20	.253	71.06	1.11
London and North Western	1882	.....	.....	.....	.....	.....	12.40	.....	.....	.....	15.10	.....	66.54	.....
	1883	1 793	68	.....	78	39	59	11.90	.392	4.69	.078	.261	65.52	1.11
	1884	1 811	68	.....	78	38	58	12.14	.209	4.78	.082	.271	65.66	1.13
London and South Western.....	1882	.....	.....	.....	.....	.....	13.60	.....	.....	.....	16.90	.....	73.28	.....
	1883	721	49	.....	71	51	56	12.78	.228	5.42	.097	.298	71.58	1.28
	1884	722	49	.....	69	51	56	13.06	.233	5.42	.097	.346	71.46	1.27
London, Brighton and South Coast.....	1882	.....	.....	.....	.....	.....	9.82	.....	.....	.....	18.06	.....	66.52	.....
	1883	403	63	.....	91	56	63	9.96	.158	4.24	.067	.289	66.08	1.05
	1884	417	62	.....	83	55	61	9.80	.161	4.48	.073	.294	63.70	1.05
Manchester, Sheffield and Lincolnshire...	1882	.....	.....	.....	.....	.....	9.26	.....	.....	.....	14.36	.....	66.18	.....
	1883	314	66	.....	77	35	62	8.92	.160	.....	14.90	.248	65.48	1.06
	1884	316	69	.....	75	34	60	8.80	.147	.....	14.26	.238	65.02	1.08
Midland.....	1882	.....	.....	.....	.....	.....	10.18	.....	.....	.....	14.94	.....	56.18	.....
	1883	1 381	76	.....	61	33	50	9.50	.190	5.24	.105	.310	56.30	1.12
	1884	1 388	76	.....	61	33	50	8.96	.180	5.06	.101	.301	56.52	1.13
North Eastern	1882	.....	.....	.....	.....	.....	12.78	.....	.....	.....	20.60	.....	69.14	.....
	1883	1 534	51	.....	78	37	62	12.36	.199	7.84	.126	.343	67.74	1.10
	1884	1 534	49	.....	76	35	59	12.38	.210	8.34	.141	.364	67.78	1.15
South Eastern	1882	.....	.....	.....	.....	.....	11.08	.....	.....	.....	17.54	.....	74.44	.....
	1883	370	55	.....	85	66	71	10.78	.152	3.88	.055	.255	74.74	1.05
	1884	369	59	.....	82	62	66	9.94	.151	3.92	.060	.261	70.58	1.07
All the Railroads of the United Kingdom.	1882	18 457	46	541 605	.....	.....	12.28	.....	.....	.....	16.42	.....	64.94	.....
	1883	18 681	46	42 417	73	43	57	12.02	.211	.....	16.64	.291	64.34	1.13
	1884	18 864	46	42 486	71	42	55	11.64	.211	.....	16.70	.304	63.18	1.15
All the Railroads of England and Wales ..	1882	.....	.....	.....	.....	.....	12.12	.....	.....	.....	16.74	.....	65.68	.....
	1883	13 215	54	49 258	73	44	57	11.74	.206	.....	16.96	.300	64.84	1.14
	1884	13 340	54	49 854	72	43	56	11.44	.204	.....	17.04	.304	63.96	1.14
UNITED STATES.														
Pennsylvania Railroad Division.....	1883	1 314	52	.....	189	45	162	17.6	.116	7.1	.047	.245	.161	.56
	1884	1 471	45	.....	205	42	160	16.4	.103	7.	.044	.238	.148	.53
	1885	1 518	46	.....	210	45	167	13.2	.080	6.2	.037	.222	.133	.41
New York Central and Hudson River.....	1883	.....	.....	.....	205	71	160	21.7	.134	6.8	.042	34.3	.214	123.2
	1884	993	53	.....	196	60	147	18.8	.128	5.2	.035	26.6	.180	108.5
	1885	993	56	.....	195	70	150	15.1	.100	4.9	.033	24.8	.165	92.8
Louisville and Nashville System, Main Stem	1883	185	21	\$85 405	149	40	109	13.15	.121	4.51	.041	20.60	.190	85.31
	1884	185	23	86 373	145	59	112	10.46	.093	4.64	.041	20.57	.184	85.39
	1885	185	21	86 804	149	58	114	10.96	.096	4.13	.036	18.67	.164	81.58
Nashville and Decatur	1883	119	15	37 198	153	39	116	17.48	.151	4.67	.039	20.47	.176	103.94
	1884	119	15	37 420	161	49	125	13.69	.109	4.68	.037	21.06	.168	97.21
	1885	119	15	37 769	162	64	128	12.57	.098	4.16	.033	20.25	.159	91.39
South and North Alabama	1883	189	17	55 357	129	34	108	21.18	.205	4.66	.045	19.67	.191	89.45
	1884	189	18	55 521	124	45	107	15.32	.143	4.74	.044	19.48	.182	87.00
	1885	189	19	55 818	117	57	101	10.99	.109	4.25	.042	18.57	.184	75.57
Mobile and Montgomery.....	1883	179	12	36 059	137	43	105	23.12	.220	4.56	.043	19.07	.181	95.38
	1884	179	13	36 119	129	52	104	28.38	.273	4.67	.045	19.42	.187	104.36
	1885	179	14	36 154	123	75	104	22.91	.220	4.09	.039	18.18	.175	92.42
New Orleans, Mobile and Texas	1883	141	12	73 052	150	64	110	18.74	.170	4.34	.039	20.86	.190	99.08
	1884	141	12	73 195	143	80	112	22.08	.197	4.54	.040	21.61	.193	107.
	1885	141	12	73 241	138	93	114	16.05	.141	3.91	.034	20.78	.174	94.07
Knoxville Branch	1883	171	4	28 200	134	42	91	50.78	.558	4.33	.048	21.25	.233	111.81
	1884	171	10	26 464	122	39	88	35.53	.404	4.60	.052	21.04	.239	93.94
	1885	171	11	26 624	126	31	91	22.16	.243	4.14	.045	19.11	.210	74.55
Memphis Line.....	1883	258	10	35 667	109	32	69	24.26	.352	4.36	.063	18.65	.270	83.74
	1884	258	9	35 702	110	39	76	22.82	.300	4.53	.059	19.65	.259	84.58
	1885	258	9	35 710	126	34	81	21.84	.270	4.00	.049	19.44	.240	84.36
Henderson Division.....	1883	151	14	41 782	126	27	93	22.17	.238	4.57	.047	19.68	.212	82.76
	1884	151	13	41 854	138	42	116	25.00	.216	4.76	.041	19.77	.170	93.77
	1885	151	13	41 904	152	45	125	15.98	.128	4.25	.034	17.29	.138	80.60
St. Louis Division.....	1883	208	8	33 108	109	32	74	34.08	.460	4.35	.060	16.45	.222	102.97
	1884	208	9	33 297	109	33	75	32.17	.429	4.56	.061	17.04	.217	101.41
	1885	208	9	33 372	122	32	82	28.32	.345	4.05	.049	15.86	.193	93.35
Cincinnati Division	1883	110	17	44 469	113	41	89	16.87	.201	4.34	.054	21.04	.263	107.81
	1884	110	18	44 689	125	51	92	15.75	.171	4.56	.049	20.26	.220	106.86
	1885	110	19	44 391	135	45	95	14.55	.153	4.05	.042	18.98	.200	103.11
Lexington Branch	1883	67	10	44 469	103	37	60	38.14	.636	4.03	.067	18.63	.310	96.84
	1884	67	11	44 533	159	48	90	27.71	.308	4.39	.048	19.16	.213	88.63
	1885	67	11	44 564	165	40	91	20.95	.230	3.90	.043	17.84	.200	78.73
Chicago, Rock Island and Pacific.....	1883	1 384	22	52 203	109	53	95	17.12	.180	3.31	.035	16.83	.177	77.50
	1884	1 384	25	52 963	110	49	94	14.08	.150	3.53	.037	16.85	.177	72.43
	1885	1 384	22	53 221	106	62	93	14.67	.158	3.18	.034	18.08	.194	74.32
Philadelphia and Erie	1883	287	26	.....	268	44	221	25.61	.115	9.32	.043	31.17	.141	107.14
	1884	287	26	.....	279	38	221	21.15	.096	9.57	.043	28.03	.127	93.68
	1885	287	26	.....	288	35	229	18.06	.079	7.77	.034	25.48	.111	83.10

TABLE No. 46.

London and North Western Railway, of England, compared with the Pennsylvania Railroad Division of the Pennsylvania Railroad, of the United States:

1884.	London and North Western.	Pennsyl- vania Railroad Division.
Total length of line operated.....	1 811	1 471
Aggregate daily trains over entire line.....	68	45
Average annual train mileage per mile of line operated	21 086	14 135
Average load of freight trains, tons.....	78	205
Average passenger trains, passengers.....	38	42
Average of all trains, tons and passengers.....	58	160
Average Cost of Transporting One ton, or One passenger, One mile.	Cents.	Cents.
Maintenance of way.....	.209	.103
Repairs and renewals of locomotives.....	.082	.044
Total cost of motive power.....	.271	.148
Total operating expenses.....	1.130	.530

From the preceding table it appears that the actual cost of transporting one ton, or one passenger, one mile on the London and North Western is about double what it is on the Pennsylvania, in maintenance of way, repairs and renewals of locomotives, motive power and total operating expenses. To this last item, for the London and North Western there should be allowed a large credit, as, owing to the average length of haul for freight being shorter on that road than on the Pennsylvania, the terminal charges are proportionately greater.

It may be said that this calculation is based entirely upon my plan for estimating the ton and passenger mileage, *i. e.*, the average charge of 1d. per ton per mile, and 1½d. per passenger per mile for ordinary tickets, and 4d. per mile for season tickets, including first, second and third-class.

For argument sake we can reduce all these prices one-half, and by making proper allowance for the difference in the price of labor and materials that constitute almost entirely the different items of operating expenses, the Pennsylvania Railroad will still be found to cost less.

Suppose we substitute in the preceding table for the Pennsylvania Railroad, the Knoxville branch of the Louisville and Nashville system. This can be considered a fair sample of the cheaply constructed American railroad. It runs through, physically, a very rough, sparsely settled country, offering no natural advantage for cheap railroading. The traffic is so small that it only justifies a total of ten trains daily. The entire average cost of constructing this road is \$26 464 per mile—less than one-ninth of the average cost of the London and North Western per mile.

TABLE No. 47.

London and North Western Railway, of England, compared to the Knoxville Branch of the Louisville and Nashville System.

1884.	London and North Western.	Knoxville Branch.
Total length of line operated.....	1 811	171
Total annual freight and passenger train mileage per mile of line operated.....	21 086	3 515
Average load of freight trains, tons.....	78	122
Average load of passenger trains, passengers.....	38	39
Average load of all trains, tons and passengers...	58	88
Average Cost of Transporting One Ton, or One Passenger, One Mile.	Cents.	Cents.
Maintenance of way.....	.209	.404
Repairs and renewals of locomotives.....	.082	.052
Total cost of motive power.....	.271	.239
Total operating expenses.....	1.130	1.069

Notwithstanding the small traffic and the cheapness of construction of the Knoxville Branch, the cost for moving one ton, or one passenger one mile, for maintenance of way, is only .2 cent more, while all the other charges are less than on the London and North Western Railway, the total operating expenses being as 1.130 to 1.069 cents or .061 cent less.

The returns or reports of the London and North Western for 1885 have not been received by me. In 1885 the Knoxville Branch made

large savings in the cost of maintenance of way, and consequently in operating expenses, comparing thus:

TABLE No. 48.

Cost of Moving one Ton, or one Passenger, one mile.	London and North Western, 1884.	Knoxville Branch, 1885.
Maintenance of way.....	.209 cents.	.243 cents.
Total operating expenses	1.130 "	.819 "

This table shows the cost of maintenance of way to be nearly the same, while the total cost of operating expenses is 27 per cent. less on the cheap than on the expensively constructed road.

Some persons state that the reason of the greater cost of the different items forming the cost of operating expenses, is owing to the greater number of trains running on a given mile of the English railroads. This is unquestionably the cause of most of the increase, but is it a good reason for it?

Can it be considered good practice to employ two men to do the same work that others are doing with less than one man? Is not this just what is being done now on the English railways, owing to the light freight and passenger trains that are run, requiring over two engines and two sets of men to do the same amount of work that the Americans do with one?

It is difficult to say what causes this great difference in the cost of maintenance of way. Undoubtedly the rigid and stiff rolling stock used on the English roads runs with more friction and wear and tear than the pliable bogie-truck used on the American railroads.

TABLE No. 49.

Comparative Cost of Transporting one Ton, or one Passenger, one mile,
in Maintenance of Way and Motive Power.

No Reports for 1885 from the London and North Western have been received.	London and North Western. Average of Years 1883 and 1884.	Pennsylvania Railroad Division. Average of Years 1883, 1884 & 1885.
Maintenance of way.....	.206 cent.	.100 cent.
Motive power .....	.266 "	.147 "
Total.....	.472 cent. .247 "	.247 cent.
Excess of cost.....	.225 cent.	

This excess is more than half of the total cost of all operating expenses of the Pennsylvania Railroad in 1885.

It cannot be said that the Pennsylvania Railroad has favored to any serious extent these two accounts at the expense of others, as the total cost of all operating expenses in 1885 was less than the aggregate of these two items on the London and North Western.

If this amount could be saved, it would, on the traffic of the London and North Western Railway, amount to an annual saving of about (\$5 000 000) five millions of dollars. This estimate is based upon the prices actually paid. This saving would be still more largely increased if proper allowances were made for the difference in the price of labor and material used on the two railroads.

I conclude this paper with the last sentence in my first paper on this subject.

"For what is done in the United States, *ought* to be done in the United Kingdom."

DISCUSSION ON

ENGLISH AND AMERICAN RAILROADS COMPARED.

EDWARD P. NORTH, M. Am. Soc. C. E., suggested that the use of the term "bogie-truck" was hardly a proper expression, as the word truck is used in America to describe an American invention, and the word "bogie" is used in England applied to the same thing; one noun is used in this paper as an adjective to explain a noun of the same meaning.

MR. DORSEY agreed with Mr. North that the simple word "truck" was more proper, but as the paper compared the railways of both continents, the terms used should be readily understood. All railroad men of Europe with whom he had conversed understood what is meant when the compound word "bogie-truck" is used, while, if the simple word "truck" is used, the meaning might have to be explained to many.

M. J. BECKER, M. Am. Soc. C. E., thought it difficult to enter upon a comparison of English railroads as a whole with American railroads as a whole, because there exists in England a certain uniformity and general standard of operation, but in this country there is practically no standard at all. Some of our roads attain a high degree of excellence, approaching, if not excelling, the best in any other country, and other roads are scarcely worthy of the name. This seems to apply not only to the construction, but to the management as well.

He also thought that in the comparison of railroad speeds the necessity for stops and grade-crossings—which stops are often compelled by State laws—should be considered in comparing such roads with those where such stops are not necessary.

E. L. CORTELL, M. Am. Soc. C. E., agreed with Mr. Becker and said that it was hardly fair to compare the speed upon one railroad with another until the curves, grades, stops, etc., should be considered.

WALTER KATTE, M. Am. Soc. C. E., referred to speed attained on the New York, West Shore and Buffalo Railway, as stated in Mr. Dorsey's paper at page 65 of the Transactions for 1886.

MR. DORSEY replied that he had taken the ground that the object of fast traveling is to get the traveler to his destination as quickly as possible, regardless of quick time between mile-posts. The table of comparative speeds which he had submitted was constructed so as to show

NOTE.—English and American Railroads compared, by Edward Bates Dorsey, M. Am. Soc. C. E., Transactions of the Society, Vol. XV, p. 1, January, 1886. Also Supplementary Paper, Vol. XV, p. 733, November, 1886.

The discussions on these papers occurred at several meetings.

the average speed between terminal and important stations, which really seems to be what is of most importance to the railroad traveler.

Capt. W. H. Bixby, M. Am. Soc. C. E., referred to methods of communication between passengers in English cars and the conductor or engineer; one was a bell-pull placed along the middle of the compartment, close to the floor; another was a bell-pull in the top of the car, placed in the partition between the compartments, and separated from the travelers by glass. There is a printed notice that, in case of accident, this glass should be broken and the bell pulled; in addition, there is a notice that if this is done without due cause, a severe fine will be imposed.

He also said, in reference to the second and third-class compartment cars in England, that there are great differences upon the different roads; some of the second-class cars being particularly good, and some of the first-class rather poor. The Midland Road has compartment cars of the lower grade well got up, and some of them as well upholstered as the first-class cars, the only difference being the number of seats put into the same sized compartments; in many of the first-class cars there are six seats, and in the third-class cars eight. In other respects the arrangements are as comfortable in one as in the other.

Mr. DORSEY replied that he had already mentioned the bell-rope on the floor, used on the London, Chatham and Dover Railway, and the electrical bell, used largely in France, but not to any great extent in England. Nevertheless he thought it safe to say that 95 per cent. of those who traveled in the United Kingdom cannot communicate with the engine driver or conductor when the train is in motion.

He could not agree with Captain Bixby that the third-class cars are as well got up, or that some of them are as well upholstered, as the first-class cars, and that the only difference is the number of seats put into the same sized compartments; his observation and experience had not led to this conclusion. The second and third-class compartments are made to seat ten instead of eight, and those compartments are smaller than the first-class; he had never seen the very comfortably upholstered third-class carriages alluded to.

O. CHANUTE, M. Am. Soc. C. E., referred to the remarks in the paper in regard to the matter of parliamentary expenses, and to the frequent allusions by persons in this country to those expenses as a great waste of money. He took a rather different view of this matter. It seemed to him that the parliamentary inquiries into the probable usefulness and economy of projected enterprises were a great safeguard against ruinous investments of money. And that, although during the last eleven years \$35 000 000 have been spent in England merely in the inquiry as to whether projected roads should or should not be completed, there have probably been spent in this country during the same

length of time over \$100 000 000 in injudicious enterprises. And that the time has probably arrived when we should be compelled to do what has been done in France and in England, that is to say, resolve to make careful inquiry into the necessity of proposed work before permitting schemers or capitalists to damage existing interests, to destroy the value of existing properties, or spend their money on parallel roads or duplicate enterprises where there are already sufficient facilities to do all the business. He called special attention to that paragraph in the paper stating that much of the business of the engineer in England consists in making careful inquiries and careful estimates of the probable value of enterprises before legislative sanction is obtained for their construction.

F. COLLINGWOOD, M. Am. Soc. C. E., said, in regard to the matter of parliamentary witnesses, that there were brought together on such occasions some of the best men in the engineering profession in the whole kingdom; that they have their offices near the Houses of Parliament; that this business is one of the best in the country; that only men of decided ability can secure such engagements, and the fees are really very large.

WILLIAM SELLERS, M. Am. Soc. C. E., thought that this question of parliamentary expenses had not been sufficiently considered. If, in comparing the cost, the parliamentary expenses are considered part of the cost of construction, then the English railways would show high construction costs, because they are short, and parliamentary expenses would therefore be large per mile; this, he thought, might seriously vitiate a comparison with the cost of completing our roads.

J. J. R. CROES, M. Am. Soc. C. E., thought that it would be interesting to know whether the parliamentary expenses in England are really larger than the legislative expenses in this country. In England there is one legislative center, but in the case of the trunk lines in this country there are a number of legislative centers. So far as he knew, there is no record kept of the expenses that a project undergoes in reaching the stage of actual construction, but he thought quite likely that the legislative expenses of carrying through any large project are about as great to the stockholders in this country as in England.

THOMAS EGGLESTON, M. Am. Soc. C. E., said that the parliamentary expenses were legitimate ones for the stockholder and bondholder, while in this country the money was often expended in improper methods of influencing legislation.

Mr. M. J. BECKER, said that he thought the improper action in this country was often quite the reverse of what Dr. Eggleston had suggested, and that the railroad companies were really the sufferers in instances where they should be protected by legislation.

CHARLES E. GOAD, M. Am. Soc. C. E., said that it seemed to be considered here that English parliamentary expenses were wisely incurred with reference to the desirability of building a proposed railroad, but he thought that at the present time the very heavy expenses in certain cases were caused by the opposition of large existing corporations, in any case where there might be a fear of future rivalry.

Mr. DORSEY said that he thought it was a mistake to suppose that the large sums charged to parliamentary expenses were for the purpose of ascertaining whether a proposed road should or should not be built, or whether it was or was not wanted, or whether it would pay or not; that part of the investigation was soon and cheaply disposed of. The great cost of the expenses generally comes from the opposition of some existing line, in the fear that its business might be injured by the proposed one.

A. M. WELLINGTON, M. Am. Soc. C. E., thought that the writer of the paper was mistaken in saying that the vacuum brake was obtaining supremacy in England; there exists at present a great controversy between the advocates of the different brakes in England, and there is not the same nearly universal practice as here. Nearly all the different kinds of brakes are in use, but he thought that the one most largely adopted was the Westinghouse automatic, and that it was decidedly gaining ground over the others.

Mr. DORSEY said that by a recent publication of the Board of Trade of the United Kingdom, there was equipped on June 30th, 1885, 11 145 engines and cars with the Westinghouse brake, and 16 093 engines with the automatic brake.

OBERLIN SMITH, M. Am. Soc. C. E., said that one of the chief reasons why wider and more comfortable cars cannot be introduced in England is that the first coaches were built upon the stage-coach model, and that there is not now room between abutments and bridges and sides of tunnels for wider cars.

Mr. C. E. GOAD thought that a longer experience in traveling upon English roads might have modified the opinions of the author of the paper as to various points. He thought that if the elevated roads of New York would adopt the method of opening their cars at the sides instead of at the ends, they would find it a great advantage. He believed that the trains on the underground roads in London could empty in one-third of the time taken to empty an elevated train in New York.

He thought the statement in the paper as to the lavatory accommodations on English trains was erroneous; there are very comfortable accommodations on nearly every train in England. Of course this is only on first-class cars; if you want to fare well you have to pay for it, just as you do in this country.

In reference to the movement of baggage, he thought that if the

English system were in use in this country it would be easier for the traveler than the present one; the baggage is in the same carriage with yourself, in a little van, and when you get out you give a porter sixpence and he gets your baggage and puts it on your cab. You can always get it at once, there is no delay; if you want to go to an evening party there is not a delay of one or two hours waiting for an expressman to come with your baggage. And the honesty of the men there is remarkable. Many Englishmen who have been away from their country for many years are fond of finding fault with everything English, but he did not propose to do so. It had just cost him quite a sum of money to get his baggage from Buffalo to Deer Park, where he was now stopping, and several hours' loss of time. In England there would have been no loss of time, and not one-third of the cost.

JOHN BOGART, M. Am. Soc. C. E., said that a few years ago Baron Von Weber, then connected with the railway systems of Germany, visited this country to make a study of our public works. He was a man of decided opinions; one of these was expressed very strongly soon after his arrival, which was that the European system of handling baggage was very much better than the American. He traveled for some time in this country, and on his return to New York said that he thought our roads were in many respects not up to European standards, but that he had learned one thing, and that was that the only way to manage baggage was with the little brass checks.

FREDERIC GRAFF, President Am. Soc. C. E., said that he thought the advantages of the different systems were somewhat due to the different habits in regard to baggage in the two countries. In England a traveler generally has his luggage in hand parcels; the distances are not so great as in this country, and the packages are much smaller. Here large trunks are taken, and he thought that there would be considerable difficulty in putting an ordinary Saratoga trunk on the top of an average cab.

Captain O. E. MICHAELIS, M. Am. Soc. C. E., thought that one of the points affecting the methods of travel was that the European traveler was required, and seemed willing to yield up his personal liberty to the railroad, while in this country a first-class passenger would insist upon the privilege of going through the whole train. Switzerland is the only country in Europe where the American system is used.

MENDES COHEN, M. Am. Soc. C. E., Chairman of the Convention, thought that many differences in the methods of constructing and operating railroads in the two countries grew out of the fact that the development of the system here began when this was a sparsely settled country, and people were accustomed in moving about to take care of themselves. The tracks were laid and the cars started from the streets; people got on them in the most convenient way, and took such seats as

they could. As the railway system developed, the people have become accustomed to taking care of themselves, and it is now only upon our great roads that we begin to see the necessity of caring more thoroughly for the passenger. This also is shown in the progress of the construction of overhead and underground crossings.

In England, on the other hand, a densely populated country, all in authority were required at the first to look out for safety and life, and they paid attention to that rather than to anything else. The passenger who was to be carried was carefully put away and taken care of; he was quite willing to submit to it; he was as comfortable as in the old stage-coach and went at a higher speed; he had always put his luggage at the top of the coach, and why not on the top of the car? This was really a sort of necessity, because, as their lines developed, a car for a branch destination was simply shunted from the trunk line, and passengers, baggage and all went together; if the baggage had been on another coach there would have been delay and trouble. It seemed to him that the English system suits the English people better than ours would, and that when we find much inconvenience with their system, it is because we are not accustomed to it. When we are there it may take us some time to learn, but after awhile we do as they do and look out for some pleasant looking porter, give him a shilling and ask him to put our baggage in the right place.

Mr. GOAD said, Oh, not a shilling, only a six-pence, you will ruin the country.

Mr. COHEN said he was afraid we had done it already.

Mr. F. COLLINGWOOD said that there was one important difference, not mentioned in the paper, between the railroads in the two countries, and that is, that at stations in England no person is allowed to cross the tracks. Some sad accidents had occurred at the place where he resides from this cause, and he thought that the English system ought to be introduced here.

Referring to the statement as to the unloading of coal, he said that he had seen cars unloaded in England by lifting up the whole car bodily and unloading it in that way.

There was one important item of cost in the running of English railroads, that is to say, if a fee of the right size is put into some official's hand a passenger can have the whole compartment to himself, the result being a great many cars for the number of people carried.

There is one trouble in regard to the baggage system in England which seemed to him important, and that is the necessity of carefully watching it at the different points. On three occasions he would have lost his baggage except for this personal supervision.

He thought that the distinction between the different classes of cars was comparatively nominal, and that the difference in price was really too great.

Dr. EGGLESTON said that he thought there should be some recognition of the average honesty of the English employee. It is true that it is necessary to look after your luggage when you get into a train, and every time the train is changed, and you have also got to see whether your luggage is taken out of the van, whether your train changes or not; but he had a personal experience in regard to some lost baggage which had been left some miles back in a change of train, but which was recovered in a few hours, in a much shorter time, he thought, than lost baggage could be recovered in the United States.

Mr. J. J. DE KINDER, C. E., said that in comparing the English and American systems, it should be noted that the short freight cars in England, on four wheels, handle freight much faster than we can with our long box cars. The cars there are so short that a good horse can handle them, while here we have to use a locomotive, and the locomotive is not always at the right spot. There the cars are moved from one track to the other without loss of time, and in the same way freight is taken on at local stations, as they would have one or two horses ready to move cars, while here we have to lose time in bringing up a locomotive.

As to the question of comfort in English cars, there certainly is an opportunity for difference of opinion; while it is true that there is only a can of hot water for warming purposes, and that may not sound very pleasant, yet in his experience of cars sometimes heated to 100 degrees Fahrenheit by steam, and then cooled off suddenly by the conductor's opening the door, and subjecting passengers to a stream of air 30 degrees below zero, he thought the comparison, so far as health is concerned, might not be without advantage to the English system.

WM. P. SHINN, M. Am. Soc. C. E., referred to the subject of the introduction of overhead or underground crossings, and to the fact that at several points, notably at Columbus and at Indianapolis, where tunnels had been constructed for the street traffic, only the street cars used the tunnels, and that was because their tracks were there; but that other vehicles and foot passengers cross on the street, keeping out of the way of trains as they best could, the lesson being that the only way to keep foot passengers and vehicles off the tracks would be to make a tunnel or bridge the only possible means of crossing.

CHARLES LATIMER, M. Am. Soc. C. E., thought that a comparison of the number of men to the mile employed in the different departments of our railroads and those of Great Britain would disclose more additional information; he thought that there were many more employees upon the English than upon the American railroads. The percentage of the employees in the different departments of the New York, Pennsylvania and Ohio Railroad, with which he was connected, is as follows, the figures being very close approximations:

Transportation.....	42.8 per cent.
Locomotive Department:	
Shop.....	16.4
Locomotive....	12.2
Car Shops.....	28.6
Maintenance of Way.....	9.5
General Offices.....	16.7
	2.4
	<hr/> 100.0

and the total number of men 4 200, or an average of 7.5 men per mile. The average amount paid per man is \$50 per month; the average paid to officers and clerks is \$100 per month.

J. FOSTER CROWELL, M. Am. Soc. C. E., thought that the conclusions which Mr. Dorsey had reached supported the impression formed by most American railroad men when traveling on English railroads. The causes of the increased cost of operating which Mr. Dorsey suggests were doubtless potent, but would hardly account for the very great differences shown, and he thought that the question should be considered more deeply, and other features of English management looked at. It is doubly unfortunate that absolute data are lacking of the volume of traffic on the English roads, because the argument is based upon conditions to a certain extent assumed, and because, perhaps, the missing facts might be susceptible of classification and analysis to enable a distinct recognition of such causes. The limited researches he had been able to make led him to the opinion that the English roads do not preserve and utilize their records to the extent usual here, and this, if a fact, would be another cause of their failure to secure economy. The figures adopted by Mr. Dorsey as the average charges for passenger and ton per mile, are doubtless closely approximate; certain American railroads carry about twice the volume of freight that is carried by equivalent English roads, with a nearly equal number of passengers in each case, and therefore Mr. Dorsey deduces that the overcrowding on English roads is not a necessary condition, if it exists. It does not follow that the overcrowding may not be due to the constitution rather than to the volume of the traffic. Upon a relatively short line, frequent, light, low speed, short distance trains, with a comparatively small aggregate annual passenger mileage might interfere with freight traffic of whatever volume, while, on the other hand, an equal volume of passenger traffic carried on long distance, through, fast trains, judiciously grouped, might produce no sensible effect on the freight. In this country, other things being the same, the cost of operating mixed traffic is found to be greater on those parts of a line where the former conditions prevail, and these conditions exist to a greater extent on the six English than on the six American roads having the most traffic, selected by Mr. Dorsey for comparison of mileage. The remedy might be in trains of a greater capacity, and in a more complete separation of freight from passenger

traffic, and by additional tracks, especially approaching terminals and distributing points. Such provision is more difficult under the English system of construction than in this country. A considerable increase in the cost of movement of freight in England results from the mingling of all kinds of traffic at the terminals. The greater cost of repairs and renewals to locomotives should be accounted for by the primordial differences in the locomotives, irrespective of the difference in material or workmanship. Both the English and American engines of the present day are evolved types adapted to the requirements in each country, but the American had to be fashioned primarily to withstand excessive shocks and rough usage. The English road-beds are superior in conformation, rigidity and precision of grades; they are more perfectly aligned; their curvature is generally light and well adjusted, and they have a higher degree of rigidity in gauge and surface; but the employment of short rails, of rigid iron chairs, generally on every tie, the absence of that yielding which is a redeeming defect of an American track, produces a reactionary effect upon rolling stock that must be very injurious. While it is true that the average American track suffers from the violent impact of heavy engines, it is probably equally true that the English engine is unduly racked by the track reaction. Mr. Dorsey's figures show that the sums of the percentages of maintenance of way, and repairs and renewals of motive power are almost equal in the two countries, which seems an illustration of the axiom that action and reaction are equal. He thought that Mr. Dorsey had refrained from alluding to one general point of difference, which is noticeable in the handling and making up, switching, sorting and distributing of trains. In these regards the English practice seems unduly costly and inefficient to one accustomed to American methods. This is in part due to the greater number of vehicles, and the more complicated couplings and other appliances which take unnecessary time, but chiefly to the lower standard of intelligence, or at least of training, of subordinate officials and employees.

G. BOUSCAREN, M. Am. Soc. C. E., said that it was a subject of gratification that, on the whole, the comparison made by Mr. Dorsey as a result of his great labor in compiling so much valuable information, was favorable to the American system, but this implies a double obligation to be fair with our neighbors and co-workers. He thought that much might be said in defense of English engineers as to what appeared to be the excessive cost of their roads. In the first place, while the charters of American railroads generally cost but little, the preliminary formalities imposed by English law were a source of enormous expense. He presented the following, taken from the work of Mr. Ch. De Franqueville, Secretary of the Railroad Commission of France, on the "Public Works in England," showing the parliamentary expenses of eight railroad companies from 1848 to 1860:

Midland.....	\$5 661 000
London and North Western.....	5 006 000
Great Western.....	4 137 000
South Eastern	2 756 000
Lancashire and Yorkshire.....	2 751 000
Great Northern.....	1 910 000
London and South Western.....	1 761 000
Caledonian.....	1 994 000
Total.....	\$25 976 000

In connection with these expenses, Mr. De Franqueville says: "Four different companies competed for the concession of the line from London to Brighton, and spent in one year in parliamentary fees over \$500 000. They were represented by twenty ordinary advocates, six sergeants, or Queen's counsels, twenty solicitors, and a strong battalion of parliamentary agents, experts, engineers, etc. A short time afterwards the Trent Valley company spent \$737 000 trying to secure the concession of the line from Stone to Rugby and did not succeed. The Great Northern bill, presented in 1845, cost the company \$3 853 000 for a line 245 miles long, being at the rate of nearly \$16 000 per mile." A careful estimate made by the same author of the average price paid by railroad companies in England for right of way not occupied by buildings, was \$1 070 per acre; to this must be added a very large amount for "damages." It is quite clear that the cost of these two items alone, namely, Parliamentary expenses and Right of way, which are entirely beyond the control of the engineer, is not far from the cost of an average American railroad.

Very few lines are now being built in England, and new construction is almost exclusively limited to short branches and connections. But at the time when the greater part of the lines were built the ordinance maps were incomplete, surveying parties could not go over the ground without the consent of the land-owners, and their consent was often refused, owing to prevailing prejudices. Observations had often to be made at night, or on Sunday during service hours when the proprietors were not at home. Various artifices and stratagems were indispensable for securing necessary information to prepare the very accurate plans required. It can be imagined how much more costly location under such conditions must have been as compared with that of our American railroads.

No fair comparison can be made of the cost and styles of construction in the two countries without taking into account the great differences of conditions under which the work was done on each side. While the English Government has no standard specifications, the apparent latitude given to the engineer is in effect very much restricted; first, by laws regulating all classes of road crossings, limiting the radius of curves to a minimum of 2 640 feet, and investing the Board of Trade

with further regulating powers which are left practically to the discretion of its inspectors; secondly, by the sharp competition which every railroad bill must invariably fight before parliamentary commissions, which opens the door to criticisms more or less reasonable, but generally supported by expert testimony and often passed upon by men more experienced in debates of politics than in the art of engineering. The result being that the highest character of work is as a rule not a matter of choice, but one of obligation with the English engineer. After being hampered in the selection of the most favorable location by the large question of land damages, the English engineer may be forced against his better judgment to spend much money for a show of security for which no direct compensation in economy or operation can be expected.

On the other hand, American engineers enjoy all desirable freedom in locating their lines and preparing specifications, but are often compelled to sacrifice economy of operation for the want of capital. These contrasting circumstances have worked altogether to the advantage of American railways. If necessity is the mother of invention, one cannot imagine a better field for discoveries in the adaptability of means to results than the condition which obtained at the incipency of railroad construction in this country. Had American engineers been saddled with the same impediments, and blessed with the same abundance of capital, it is not improbable that we would have done very much as they did in England.

Referring to the remarks of Mr. Dorsey comparing the cost of construction and operation in both countries, the same being:

For England per mile.....	Construction.....	\$202 227
	Operation.....	10 000
For the United States per mile..	Construction.....	62 176
	Operation.....	4 410

and the percentage of annual expenditures that is affected by good or bad construction having been found to be eight per cent. greater for the United States than for England, the author concludes as follows:

"If all the railroads in the United States had been as well constructed as in England, that is, at an additional cost of \$140 051 per mile, there would have been saved eight per cent. of the annual operating expenses, which average \$4 410 per mile. Eight per cent. of this amounts to \$353, which would have been the amount saved by expending \$140 051 more per mile; this equals 0.25 per cent. on the additional cost. In other words, it would have required an additional expenditure in construction of \$140 051 per mile to save annually \$353 in working expenses. On the other hand, if the English roads had been built on the American plan at \$140 051 less cost per mile, their working expenses would have been increased eight per cent, or \$800 per mile annually. To save this, \$140 051 has been expended per mile."

Mr. Bouscaren said that it did not follow from the fact that English roads did cost \$140 051 per mile more than American roads, that American railroads would have cost \$140 051 more than they did if they had been built as well as the English, on the contrary, it is quite evident from the author's own figures that they would not. Also that it is difficult to see what parliamentary expenses, the cost of the right of way, the large expenditures for road crossings, and the interlocking system of block signals prescribed by the Board of Trade, and which enter for a large proportion in the surplus cost of English railways, have to do with the saving of operating expenses. The block system and the numerous road-crossing bridges are, on the contrary, a source of much additional expense for maintenance. The conclusions drawn by the author from this comparison are therefore misleading. Nothing is more adverse to correct results in all branches of scientific investigation than reasoning on generalities without a proper analysis of the subject. Engineering is not an exception to the rule, and the question of the cost of construction of a railroad in its bearings on the cost of operation is particularly one of great complication; it requires, as a preliminary, that under both headings of "construction" and "operating expenses," a careful classification should be made of all parts correlated to each other. In the absence of the necessary data for such classification, either for the American or English railroads, no fair comparison can be made between them with regard to the question as to how far the engineers were justified in their expenditures for construction.

He thought it beyond discussion that for important roads it generally pays to build permanent instead of temporary structures; to provide a thorough rather than an insufficient drainage for the road-bed; to have a well ballasted track and a weight of rail proportioned to the traffic. The question of distance, curvature and grade is not so simple, being dependent in a very large measure on the volume and character of the traffic. Between two possible locations for a road, the elements of cost, distance, curvature and grades must be equated to find the relative value of the two lines, and according to the quantity and character of traffic assumed as a basis for comparison, one or the other line may be found the most profitable to build. The cheaper line, even with greater length, steeper and longer grades and curves, may be found to give the largest returns for the capital invested, with a light traffic at high rates, and the reverse may be the case for a heavy tonnage at low rates. In making such comparison he ventured to say that scarcely two engineers could be found who would attribute the same coefficient of value to the different elements of distance, grade and curvature. This only proves the lack of reliable data as to the influence of each on the cost of operation, and this penury of information in its turn comes from the extreme difficulty, in all experiments that have been made on the subject, of apportioning correctly to each cause the wear and tear and consumption of

power attributable to each. This subject will always remain a useful field of investigation, especially in this country, where it will often occur that lines cheaply constructed at first can profitably be changed or improved after a time to meet different conditions of traffic.

In comparing maintenance of way expenses, it must be borne in mind that on English railways a much larger amount is spent for "fancy work," having no direct bearing on the safety and economy of operation, than on American railroads. He does not agree with the author as to the general proposition that severe winters are necessarily a cause of larger expenditures; his experience is rather to the contrary, that a mild and wet winter is a source of greater expense than a very cold one. A very large proportion of maintenance of way expenses is entirely independent of the traffic, depending solely on the physical conditions of climate, weather, topography and character of the material forming the road-bed and structures. On the Cincinnati Southern Railroad, where nothing was spent for fancy work, this proportion was 52 per cent. in 1884.

Referring to the motive power and rolling stock, Mr. Bouscaren says that this seems to be the weakest part of the English system. The comparative figures and tables given by the author show to a surprising degree that the American locomotive hauls more tons of freight and more passengers, runs a greater distance, and costs less for fuel and repairs than the English engine, whilst with the easier grades and curves and the better track of English roads the reverse should be the case. This should certainly be a matter for serious consideration, Mr. Bouscaren thinks, by English engineers and managers. There cannot be a great difference in the efficiency of the English and American locomotives, considered as steam motors. The greater speed of English freight trains and the greater proportion of stops at way-stations, explains only a part, he thinks the smaller part, of this great disparity of results; the principal cause is to be found in the advantages to the American system derived from the universal application of the bogie truck.

Mr. Bouscaren agrees with the author that neither of the two systems is perfect in itself, and that each can profitably borrow from the other. He thinks that as a rule we are perhaps too slow in following up the growth of traffic on our main lines with permanent improvements. That probably a great many roads which are now earning just enough to pay expenses and interest, could, by the judicious expenditure of more capital in the replacement of their wooden trestles and bridges with permanent structures; in a better ballasted track and heavier rails; in better drainage and protection of their road-bed; save enough on their maintenance of way expenses and cost of transportation to pay a small dividend to their stockholders. He also thought a better system of inspection and test of materials and supplies very desirable. We were very far behind England in this respect, and the saving of money

arising from the purchase of inferior rails alone would be sufficient to change many annual balances from a deficit to a surplus. Referring to the application of the compound system to locomotives, the favorable results obtained on the London and North Western, and on several of the French and German lines, are a test of its practical value.

Mr. Bouscaren does not agree with the author in advocating the indiscriminate application of the block and interlocking system to all our roads in imitation of those of England. The absolute block would be impracticable on most of our single track roads, as long blocks would very much reduce the capacity for traffic on many, and the cost of the plant and expense of operating blocks of such length as would accommodate the business would be entirely beyond the means of most of them. From the statistics of killed and wounded in both countries given by the author, it does not appear that the traveling public and employees enjoy a greater immunity from accidents in England than here.

As to the parliamentary expenses, etc., he thought it scarcely to be hoped that the conservative methods of England will admit of such reform being made in its government regulations as will save the roads that are yet to be built from the great burden of parliamentary and other unprofitable expenses, but thinks that there is ample room for improvements in other directions. If it will not pay them to increase the width and head-room of their tunnels and bridges to admit of larger cars being used, they can surely add to the comfort and security of their passengers by a different internal arrangement that will provide toilet accommodations; communication with the conductor and with each other; a better system of heating and ventilation; and more liberty of motion, a privilege highly appreciated by any one engaged on a long journey. Also that the check system for baggage should be adopted by them on the ground of comfort and economy.

As to the extraordinary method described by the author as being used to supply brake power on heavy trains, he thought it undoubtedly an abnormal remnant of the past, which is likely to be soon superseded by one of the several good systems of automatic brakes now in successful operation here. The ability of the bogie truck to keep the track at high speed is no longer a subject of controversy or doubt by any one connected with American railroads; its general introduction in England would mark a golden era in railway operation in that country, and that is only a question of time; when it is done he thinks that the greater part of the extraordinary difference in "locomotive charges" and "repairs of carriages" in the two countries will disappear. He thought, however, that it is clear that with their own thorough construction and all our improved appliances combined, the railroads of England must remain inferior to those of America if their value as such is measured by the cost of transportation; in other words, the cost of transportation in England will always be greater on account of the enormous capital

expended on parliamentary requirements without adequate results in the economy of operation. The advantage which England possesses now in cheaper material and labor is decreasing every day by the gradual equalization of the prices of labor in the two countries and the rapid development and improvement of our mining and manufacturing industries. Coal is already as cheap here as it is in England, and Mr. Bouscaren thinks the day is probably not far distant when iron and steel will also be.

Mr. DORSEY said that Mr. Bouscaren was mistaken in thinking that the author blames the English engineers for the great cost of the English railroads; he merely gave the facts as they exist, without blaming any one. Mr. Bouscaren, in common with many others, over-estimates the importance of land damages, right of way, and legal and parliamentary expenses in making up the total average cost of \$202 227 per mile. The highest estimate given for the average cost of land per mile is \$20 000; add to this the \$16 000 (which is given by him as an example of excessive charges) as the average cost per mile of the Great Northern in parliamentary expenses. Take this as the average of all English roads, this gives:

Average cost of right of way and damages.....	\$20 000
“ parliamentary and legal expenses.....	16 000
Total per mile.....	<u>\$36 000</u>

Leaving \$166 000 as the average cost of construction per mile, which is very high. Considering the low price of labor and materials, the cost is much greater than ours, including everything.

GEORGE DOWNE, M. Am. Soc. C. E., said, by letter, that he had hoped to prepare a comparison of the railways of the Australian colonies similar to those made by Mr. Dorsey, but he found that the reports of the colonies would not allow of comparison at all points in the manner desired. It appeared to him that Mr. Dorsey's comparisons were erroneous, in that, in Table No. 53, for instance, of Mr. Dorsey's paper—the basis upon which the comparison is made is the percentage cost of items on total operating expenses—any comparison in this form can hardly be otherwise than of an erroneous and misleading nature. It does not follow because a certain service is performed in America at a smaller percentage of the cost upon total operating expenditure than in England, that the result has necessarily been secured by better management and by the practice of more rigid economy. If under any certain head of service the expenditure is a fixed amount, then as the other items which make up the total operating expenses are high or low in cost, so also must the percentage of the particular item be affected. For instance, suppose that on a railway line in Australia the operating expenses amounted to £100 000, and of this sum the wages of drivers

and firemen cost £10 000, the percentage would of course be 10; but if the same item at English rates should cost £5 000, the percentage on total expenditure would not be 5, because the item being reduced by £5 000, the total expenses would be reduced by the same amount, so that £95 000, instead of £100 000, would properly represent the total, and the percentage on that amount would be $5\frac{1}{2}\%$. In the calculations submitted in Mr. Dorsey's Table No. 53 he has lost sight of this fact, and in showing what the percentage cost of wages of drivers and firemen would be in America if English rates obtained, he has simply reduced by one-half the actual percentage worked out on American cost, because English rates are 50 per cent. lower, overlooking the fact that if the items were obtained at half the American cost, so would the total operating expenses be reduced. To work out the percentage of the English cost of an item and include that item in total operating expenses at the American cost, certainly places the working of the American roads in a favorable light at the expense of the English companies.

Suppose that in America the wages of drivers and firemen were reduced to English rates, would not the cost of all other labor fall in the same proportion, and would not this reduce total operating expenses throughout, increasing the percentage cost of wages of drivers and firemen on the total operating expenses? Undoubtedly this would be so, and any item of cost included in total operating expenses would affect the percentage cost of another item, making it high or low according to the prices paid. This same method has been followed in Mr. Dorsey's tables showing the percentage cost on total operating expenses of fuel and of repairs and renewals of locomotives, and only erroneous deductions can follow. For instance, a railroad in America costs, say for one year, total operating expenditure of £500 000; of this sum the cost of fuel is £50 000; wages of drivers and firemen, £25 000; renewals of locomotives, £15 000, which would give the percentage cost three items, as 10, 5 and 3. Now, suppose that in England the same line pays £20 000 for its fuel, but exactly the same amounts for wages of drivers and firemen, and repairs and renewals of locomotives, and at the same time obtains materials for carriage and wagon repairs, and the labor in connection therewith, at rates sufficiently low to reduce the total operating expenses a further sum of £30 000, the total operating expenditure on the English line would be £440 000, and by computing the percentage cost of the items under consideration, the result would be, fuel, $4\frac{1}{2}\%$; wages of drivers and firemen, $5\frac{1}{2}\%$; repairs and renewals of locomotives, $3\frac{1}{2}\%$. Here we have two lines paying exactly the same amounts for wages of drivers and firemen, and for renewals and repairs of locomotives, yet, comparing their operations on the basis of percentage cost of total operating expenditure, the American line appears to be much less than the English, and it is in this form that the comparisons are submitted by Mr. Dorsey.

TABLE A.—AUSTRALIAN GOVERNMENT RAILWAYS.

Some particulars as to the work performed, and the operating expenses incurred during the year 1884, as gleaned from the reports published by the different colonies.

NAME OF COLONY.	Average miles of railway line operated in 1884.	Total operating expenses.	Total tonnage hauled one mile. (Load and rolling stock.)	COST OF LOCOMOTIVE BRANCH.		COST OF TRAFFIC BRANCH.		COST OF WAYS AND WORKS BRANCH.		COST OF GENERAL CHARGES.		RESULTS.				Average gross tonnage hauled over every mile of line operated.
				Total amount.	Cost per gross ton per mile.	Total amount.	Cost per gross ton per mile.	Total amount.	Cost per gross ton per mile.	Total amount.	Cost per gross ton per mile.	Working expenditure per gross ton per mile.	Receipts per gross ton per mile.	Profit per gross ton per mile.	d.		Tons.
New South Wales	1 432	£ 1 301 259	Tons. 1 087 662 219	£ 509 554	.1124	£ 310 211	.0139	£ 367 317	.0811	£ 44 107	.0100	d. .29	d. .46	d. .17	759 471	
Victoria†.....	1 655	1 277 425	*	492 627	....	442 722	....	281 475	....	60 601	....	....	....	....	....
Queensland.....	1 123	387 535	215 816 715	119 683	.1331	11 502	.0895	157 350	.1750	.....	....	.40	.76	.36	192 179
South Australia†.....	1 013	372 187	202 532 339	136 103	.1612	106 367	.1265	106 422	.1261	16 018	.0190	.44	.66	.22	201 927	

* No information in report from which this information could be ascertained.

† Services of Railway Commissioners not included in the Victorian report of total expenditures.

‡ Exclusive of cost of horse power used on tramways, and inclusive of the above.

TABLE B.—AUSTRALIAN GOVERNMENT RAILWAYS.

Some particulars of the ton mileage, load and rolling stock, with the proportion of dead weight hauled to load carried.

NAME OF COLONY.	WEIGHT OF LOAD CARRIED.			TON MILEAGE OF LOAD.			TON MILEAGE OF ROLLING STOCK.			GROSS TON MILEAGE.		PROPORTION OF DEAD WEIGHT HAULED TO LOAD CARRIED.		
	Coaching.	Goods.	Total.	Coaching.	Goods.	Total.	Coaching engines and carriages.	Goods engines and wagons.	Total.	Weight of load and rolling stock hauled one mile.	Tons.	Coaching.	Goods.	Total.
New South Wales	Tons. 763 014	Tons. 3 124 425	Tons. 3 889 439	Tons. 11 591 674	Tons. 169 563 980	Tons. 181 147 653	Tons. 293 566 711	Tons. 612 967 845	Tons. 906 534 556	Tons. 1 087 569 219	25.32	3.62	4.90	
Victoria*	2 367 352	2 272 361	4 639 713	No information in report to admit of these particulars being submitted.										
Queensland*	60 737	408 635	478 372	†	†	†	†	†	†	†	‡ 1215 816 715	.....	.....	.....
South Australia|| .	276 403	955 973	1 232 376	3 469 649	31 795 322	35 264 971	79 713 597	87 554 671	167 268 268	202 533 239	25.	2.76	4.74	

* Only the number of passengers given in the reports of the railways of Victoria and Queensland. The tonnage of load carried has been estimated by allowing the usual number of passengers to the ton, and for the balance of coaching traffic taking the same proportion or ratio as experienced in New South Wales.

† No sufficient information in report to admit of these particulars being ascertained.

‡ The weight of each engine in steam is given, and the average weight behind tender is also published. From this source the gross ton mileage, vehicles, and load have been computed.

§ Tramways included in South Australian reports; and, from the way in which the returns and accounts are submitted, it is not possible to accurately separate the railway and tramway traffic.

TABLE C.—AUSTRALIAN GOVERNMENT RAILWAYS.

Particulars as to the length of line operated; the rolling stock in use; the average weight of same per vehicle; and the train mileage run during the year 1884.

NAME OF COLONY.	Gauge.	Average length of line operated, 1884.	ROLLING STOCK USED IN TRAFFIC.				AVERAGE WEIGHT OF ROLLING STOCK.				Train mileage.
			Number of engines.	Number of coaching vehicles.	Number of goods vehicle.	Total pieces of rolling stock.	Engines.	Coaching stock.	Goods stock.		
		Miles.					T. c. q.	T. c. q.	T. c. q.		
New South Wales.....	Ft. In.	1 432	336	776	6 938*	10 345	52 15 1	8 15 0	5 0 2	6 403 041	
Victoria.....	5 3	1 655	305	702	4 797	5 804	†	.....	.....	6 849 818
Queensland.....	3 6	1 123	125	142	1 865	2 132	19 17 0	‡	.....	2 192 454
South Australia.....	{ 3 6 } { 5 3 }	1 003	118	222	2 980	3 320	34 10 0	7 15 2	3 11 1	1 732 716 ||	

* Also 2 295 private coal trucks.

† No information relative to the weight of rolling stock is given in report of Victoria.

‡ No information relative to the weight of rolling stock other than locomotives is given in report of Queensland.

|| Tramways included.

TABLE D.—AUSTRALIAN GOVERNMENT RAILWAYS.
Particulars of the principal items of locomotive expenditure incurred during the year 1884.

NAME OF COLONY.	Total operating cost.	Total tonnage hauled one mile (load and rolling stock).	COST OF FUEL.		WAGES OF DRIVERS AND FIREMEN.		COST OF REPAIRS AND RENEWALS OF LOCOMOTIVES.		COST OF REPAIRS AND RENEWALS OF CARRIAGES AND WAGONS.		TOTAL RUNNING COST.		Total operating expenses exclusive of motive branch.
			Amount paid.	Cost per gross ton per mile.	Amount paid.	Cost per gross ton per mile.	Amount paid.	Cost per gross ton per mile.	Amount paid.	Cost per gross ton per mile.	Amount paid.	Cost per gross ton per mile.	
New South Wales	£ 1 301 259	Tons. 1 087 562 219	£ 83 268	d. .0183	£ 128 931	d. .0284	£ 95 067	d. .0210	£ 79 833	d. .0176	£ 296 169	d. .0653	£ 509 654
Victoria	1 277 435	" 124 532	124 532	....	102 782	....	91 435	....	7744	....	305 554	....	492 627
Queensland	359 535	815 816 715	†	....	....	....	....	....	....	....	....	....	119 683
South Australia.	372 187	202 533 239	37 394	.0443	23 306	.0271	25 124	.0200	22 261	.0264	110 555	.1310	136 183

* No information in report to admit of this information being ascertained.

† The particulars relating to the expenditure of the locomotive branch in Queensland are confined to the following brief entry:
Locomotive working—Salaries, wages, fuel, etc. £
Stores £

Total..... £

‡ Exclusive of cost of horse power on tramways.
In New South Wales the cost of holidays and sick pay to employees are not included in the wages cost shown under the different services, but are shown to separate schedules; in the other colonies, however, these items would appear to be included under the head of "Wages."
In South Australia all wages incurred in "running" are shown under the head of "Running wages." The amount shown to drivers and firemen in this return has been arrived at from the information afforded in a detached statement published in report showing number and classification of all employees in locomotive branch during the year. The wages of cleaners, pumpers, coalmen, etc., being computed from the daily rates and deducted from the total amount of "Running wages," the balance gives the wages of drivers and firemen. The wages of coalmen has been computed and added to the fuel cost, because in the other colonies this item is charged to cost of fuel. In New South Wales the average daily rate of pay of a driver is 18s. 1d. per day, and of a fireman, 5s. 1d., as against 11s. 8d. and 5s. 4d. respectively, in South Australia. Victoria and Queensland omit all information as to rates of pay to employees.

In the absence of any direct information as to the actual ton mileage of the English railways, Mr. Downe was inclined to receive the figures of the paper under discussion with much caution. Doubtless the different systems of keeping account of returns adopted by the different railways, present serious and perplexing difficulties in the way of an impartial comparison between the railways in the different parts of the world; and unless very careful discrimination be exercised in analyzing the different systems and accounts, erroneous conclusions are almost sure to be arrived at. It appeared to him that the only true basis of comparison is the ton mileage, and the sooner railway companies all over the world come to recognize the value of this, the better will it be for placing on record lucid and reliable information. The ton mileage of load carried, coach and goods separately, should be compared with the ton mileage of the rolling stock used in its transition, with the object of ascertaining the haul to the load carried, a most important consideration, and the expenditure in working under each particular head of service, with the gross tonnage moved over the rails. By this system of comparison the actual work performed can be seen at a glance, and were the different railroads to furnish particulars of their operations in this form, with a knowledge of the road, as to its length, gradients and curves, it would be easy to properly estimate the nature and extent of the work performed and the working cost incurred.

It will be seen by some tables sent herewith, that in Australia the diversity of the systems whereby particulars of railway operations are placed before the public is somewhat astonishing. But he had no doubt the same diversity would be found in America and in England. He regretted that he had been unable to obtain such reports for the other colonies.

In the New South Wales reports, very full and lucid statements are given as to all details of railway operation. In the tables presented herewith it will be seen that the report of railway operations in South Australia more closely approaches that in New South Wales in completeness; but, unfortunately, the operations of the tramways are included in the railway returns, and in such a form as to prevent the separation of items under the respective services. The report of Victoria is anything but satisfactory; the goods and passenger train mileage are not shown separately, nor weights of rolling stock given; the number and classification of employees, with rates of pay, are omitted; no information is afforded as to ton mileage, and the mileage run by each engine is not furnished; nor is a detailed statement as to the condition of locomotives and rolling stock available.

The Queensland report is voluminous, and might have been more condensed. There is no information as to ton mileage of coach and goods traffic; nor is the train mileage coaching and goods shown separately. Particulars as to rates paid in wages are omitted. In order that

some comparison relative to the working of the Australian railways may be secured under the system advocated, the tables submitted herewith have been prepared, and it is thought that they speak for themselves without detailed explanation. The incomplete returns of the Victoria railways, unfortunately, throws that colony almost entirely out of the comparison; and, considering the extensive nature of railway operations in Victoria, it is greatly to be regretted.

ROBERT L. HARRIS, M. Am. Soc. C. E., asked what was probably meant in Table "B" in the column headed "Proportion of dead weight hauled to load carried." For instance, the figures 3.62, under the heading of "Goods," he thought meant there was 3.62 times as much vehicle as load.

MR. A. M. WELLINGTON said that the usual proportion in this country is 7 tons of load to 10 tons of car. These Australian figures would indicate something less than 3 tons of load to 10 tons of car.

MR. E. P. NORTH said that if the figures in the table in reference to coaching were correct, they would have 2½ passengers to an average Pullman car.

H. STANLEY GOODWIN, M. Am. Soc. C. E., thought that the figures 3.62 were correct, and that the fact stated was that the dead weight is 3.62 times the load; he knew that we obtained much better results in this country; the average weight of cars in general use here will come to a little more than half the capacity of the car. A car of 30 000 pounds capacity will weigh a little more than 15 000 pounds. In the coal traffic the car is fully loaded one way, and comes back empty, in this way you have 40 000 pounds load one way and when hauling the cars both ways you get 40 000 pounds of car. The coal tonnage, of course, is exceptionally good, but the general tonnage for freight would average something like that. The result given for Australia shows a great deal more dead weight carried in proportion to the load than is the case in this country; the attention of our Members in Australia should perhaps be called to this fact.

MR. EDWARD P. NORTH presented figures obtained in reference to freights in England from the report of Sir Bernard Samuelson, made to C. M. Norwood, President of the Association of the Chambers of Commerce of the United Kingdom. Complaints having been made by some one in Great Britain that the freight charges were too high, Sir Bernard Samuelson gathered carefully this information in regard to rates on railways in Germany, Holland, etc., and compared the charges with those on the English roads. In the tables submitted herewith, the rates so obtained for the roads in Great Britain are compared with the present trunk line rates between Chicago and New York, which had been given to Mr. North by Mr. S. F. Pierson, of the Trunk Pool Commission.

Attention was called to the fact that though the distance between Chicago and New York varied by different routes from 912 to over 1 100 miles, all the rates, being equal, are computed for a distance of 1 000 miles; and also the fact should be noted that the distance hauled here is much greater than in England, giving a larger divisor for terminal expenses; on the other hand, it may be noted that the volume of traffic is greater in England than in this country.

TABLE SHOWING FREIGHT RATES ON ENGLISH AND AMERICAN RAILROADS.

All the rates are given in mills per ton mile. The pound is valued at \$4.84

PIG IRON.		English.	Amer.
Barrow to Sheffield.....	122 miles	14.5	5.
" Birmingham.....	161 "	16.	5.

IRON WIRE, PACKED AND UNPACKED.

Birmingham to Coventry.....	19 miles	110.	and 63.6	7.
" Manchester.....	64 "	49.	" 30.	7.
" Liverpool.....	97 "	46.9	" 30.	7.
" London.....	113 "	50.3	" 32.4	7.
" Hull.....	132 "	46.	" 32.	7.
" Glasgow.....	236 "	29.	" 22.5	7.

HARDWARE.

Birmingham to Manchester.....	84 miles	51.	12.
" Liverpool.....	97 "	48.3	12.
" London.....	113 "	50.5	12.
" Plymouth.....	222 "	41.	12.
" Glasgow.....	286 "	31.	12.
" Edinburgh.....	298 "	26.6	12.

SAWS AND TOOLS.

Sheffield to Hull.....	53 miles	59.4	12.
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COTTON YARNS.

Manchester to Hull.....	92 miles	47.4	15.
" Newcastle.....	142 "	39.2	15.

COTTON GOODS, EXPORT AND HOME.

Manchester to Liverpool.....	31 miles	53.2 and 82.	15.
" Hull.....	92 "	47.	15.
" Birmingham.....	84 "	61.	15.
" Bristol.....	117 "	42.3	15.
" London.....	200 "	25.5 and 43.9	15.
" Exeter.....	266 "	39.7	15.

WOOLEN, WORSTED AND STUFF GOODS.

Bradford to Manchester.....	40 miles	87.	15.
" Birmingham.....	120 "	58.3	15.
" London.....	196 "	48.7	15.
" Glasgow.....	210 "	47.2	15.

EARTHENWARE AND CHINA. NOTE TRUNK LINE RATES.

China, 15; earthenware, 7 mills per ton mile.

Stoke to Birmingham.....	45 miles	53.7 and 77.	15. and 7.
" London.....	150 "	31. " 50.	15. " 7

GENERAL MACHINERY, EXPORT AND HOME.

		English.	Amer.
Leeds to Hull.....	51 miles	59.2 and 118.5	7.
" Newcastle.....	100 "	27.8 " 34.3	7.

AGRICULTURAL MACHINES (IRON), EXPORT AND HOME.

Banbury to London.....	78 miles	80. and 99.	7.
Bedford ".....	50 "	90.4 " 106.4	7.
" Liverpool.....	152 "	65.8 " 86.	7.

SUGAR.

Liverpool to Manchester.....	31 miles	85.8	5.
Hull to Sheffield.....	53 "	53.	5.
London to Northampton.....	67 "	39.	5.
" Sheffield.....	162 "	22.4	5.
Greenock to Newcastle.....	186 "	17.	5.

COTTON.

Liverpool to Manchester.....	31 miles	56.	5.4
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WOOL.

Liverpool to Manchester.....	31 miles	71.	9.
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TEA.

Liverpool to Manchester.....	31 miles	84.5	15.
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ORANGES.

Liverpool to Manchester.....	31 miles	71.6	12.
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TALLOW.

Liverpool to Manchester.....	31 miles	61.7	6.
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BACON AND HAM.

Liverpool to Manchester.....	31 miles	71.	6.
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GRAIN AND FLOUR.

Liverpool to Birmingham.....	97 miles	31.	5.
Bristol ".....	94 "	20.	5.

The first price, where two are given in the English rates, is for goods to be exported.

The American rates given in this table should be multiplied by $\frac{11}{10}$ for exactness of comparison, because the English rates are on gross and the American on net tons. For example, the rate as given from Liverpool to Birmingham, 97 miles, on grain and flour, is \$3.01 per gross ton, and the rate as given from Chicago to New York, 1 000 miles, is \$5 per net ton and \$5 60 per gross ton. It will be noticed that the average of the American rates here given are $8\frac{1}{2}$ per cent. of the average English rates.

In this connection it would be of interest to know if the British rates are ever "cut," and to what extent freight cars are allowed to stand on private side tracks for the convenience of shippers and consignees. As has been shown here, railroads sometimes allow consignees to retain freight cars for a week or more without extra charge.

In England getting a railroad charter is a very difficult and expensive

proceeding. It requires parliamentary proceedings, with a high class of parliamentary engineers and lawyers, which we understand are expensive luxuries; the result is that the few railroads in the country have in reality a monopoly; they have formed a strong pool among themselves; they do not compete in prices. The general public pays for this. Here we get low rates because by our general railroad laws competition is more active than in any other country. He thought that the rates here were, taking them all through, not more than one-half, or perhaps one-third of those in England, which are the highest in the world. He also thought that we have better railroad men than in England; that our locomotives run more miles and haul more freight at a smaller cost for repairs. We put comparatively a small capital in our roads, and, as Mr. Dorsey says, it is profitable to open a road on a small expenditure of capital, improving it afterwards when the rates will be lower. He called attention to the fact that the rates given for trunk lines in the table are the published American pool rates; nobody supposes that the companies ever get more than these published rates; they are sometimes accused of taking very much less.

Mr. A. M. WELLINGTON said that he would like to inquire of Mr. North whether the English rates which he had read were not gotten up by some one anxious to make them appear as high as possible, and who therefore went through all the rates to pick out the big ones.

Mr. E. P. NORTH replied that the rates were professably gathered to influence legislation in England, and that he knew of few higher; they are in fact mentioned as the maximum rates; at the same time notice should be taken of the fact that they are between the principal manufacturing and commercial centers of the country, and therefore may be considered as governing rates in the transportation of the country.

Mr. H. STANLEY GOODWIN thought that if they were any higher they would have to take the goods in part payment for the freight.

W. HOWARD WHITE, M. Am. Soc. C. E., said that Mr. Dorsey had expressed an opinion in favor of steel ties, thinking that they might be more economical under certain conditions, and he asked Mr. Dorsey whether he knew how long the metal ties would last.

Mr. DORSEY said that he had seen some that had been down five years and they seemed to be perfectly good. It is claimed that by Dr. Angus Smith's coating they are perfectly protected against rust, and the jar of the trains does not seem to affect this coating. Of course, where a good tie can be bought for sixty cents, he did not think the metal ties would be as cheap. In England the creosoted ties are largely used; the holes for the spikes are first bored, and after all work on the tie is done, the creosote is applied. He thought that by this process the life of the tie was prolonged for four years.

Mr. W. HOWARD WHITE said that he had made some figures in reference to the comparative cost of different ties, assuming the fund for replacing as being at compound interest at $4\frac{1}{2}$ per cent.; these figures are as follows :

Georgia pine (assuming the ties to last eight years), first cost, delivered in New York.....	\$ 70
Hauling and laying.....	20
Fund to replace every eight years.....	2 13
Total.....	\$3 03
Steel ties (8 feet long by 10 inches by $\frac{5}{8}$ inch cross-section, same to last fifty years) first cost at $1\frac{1}{2}$ cents per pound.....	1 80
Laying.....	20
Fund to replace every fifty years.....	25
Total.....	\$2 25
Preserved hemlock (to last twelve years), first cost, with laying.....	78
Fund to replace every twelve years.....	1 12
Total.....	\$1 90

Thus we have:

Preserved hemlock.....	1 90
Southern pine.....	3 03
Steel.....	2 25

M. N. FORNEY, M. Am. Soc. C. E., thought that Mr. Dorsey was mistaken in saying that in England account was not kept of the ton mileage. In the early part of his paper there is an estimate made of the cost per ton per mile. If it is a fact that the ton mileage is not given by the English roads, he could not see how the writer of the paper could get at the cost per ton per mile. If the ton mileage is not known, then the figures given with reference to the cost per ton per mile were merely shrewd guessing, therefore unreliable.

Again, he referred to the fact that Mr. Dorsey called attention to figures taken from the report of the Railroad Commissioners of the State of New York, but a study of those reports could not fail to show a lack of precision, particularly with reference to comparisons. The New York Central Railroad, for example, he supposed was obliged to report its expenses for fuel, but that road did not keep an account of the cost of fuel used on locomotives unless in the aggregate purchases of coal made for the whole line of the road. The figures therefore given in the State Commissioner's reports must be taken with a large grain of allowance.

In relation to the efficiency of locomotives, when it is attempted to make a comparison of the cost of fuel in proportion to the service performed, the great difficulty will be at once met with of finding any

correct measure for such a comparison. Even assuming that you have two roads running side by side, it is difficult to get any exact measure of the work done by different locomotives. Taking this into consideration, he thought that these figures could not be depended upon as presenting the actual differences of cost for these services in England and America.

In regard to the comparison of English and American locomotives, undoubtedly the English locomotive is adapted for use in that country and it is a very efficient machine. On the other hand the American locomotive has been adapted to use here. One of the chief differences in the locomotives is that the English use inside cylinders and we outside cylinders; they use plate frames and we use bar frames. There can be no doubt that so long as the English people use the short rigid wheel-base for their locomotives it makes their engines unsteady to use outside cylinders, but if they used a truck and lengthened the wheel-base that defect would be remedied. The English, not having had experience with outside cylinders, did not attach them so as to give that stability which we know is required, and, as a result they worked loose, which led the English to abandon them. In this country we have had so much experience with outside cylinders that we have learned to fasten them securely, and engines with outside cylinders do not shake themselves to pieces here. He thought that the argument was in favor of the American type, and that if a fair trial was given it, it would be found equal in efficiency and less expensive to maintain than English engines are.

Mr. A. M. WELLINGTON regretted that he had to disagree to some extent with Mr. Dorsey's views in reference to the differences in expenses as stated by him. In comparing in this way by percentages, things are compared which cannot well be compared with each other; the English roads have short tracks and immense terminal switching and other expenses; their switch tracks are something like three times as many as those of our American roads. Whether a road is running three trains past a station or one it has to pay one agent, and its expenses are naturally not relatively so large in the first case; that is one reason why their roads show an increased ratio in this respect on general running expenses. The greater the amount of continuous haul the smaller, comparatively, will be this expense. Thus, on the United Railroads of New Jersey it amounts to about 46 per cent., and on the Pennsylvania Road it is about 63 per cent. According to Mr. Dorsey's argument this would indicate that the Pennsylvania was having an immensely large expense for the difference of curvature and grade in their working expenses; the real reason is simply that the United Railroads of New Jersey is a short line which has an immense amount of terminal and other expenses, while the Pennsylvania main line has no terminal ex-

penses to speak of; it receives loaded cars and passes them over its lines, and naturally the running expenses in comparison with a road having a great amount of terminal and station expenses bear a small ratio. It is hardly fair to compare English roads with a line like the Boston and Albany, which has very few, if any, branches, and the New York Central Road, which is more than half main track (the Pennsylvania Railroad has a larger proportion of branches, and its main line is over one-third of its total), as these English roads are composed of irregular spurs branching out all over the country. Our large trunk lines, starting through trains from the West with a large amount of traffic, hauling their cars directly through to the terminus, naturally have their train average higher than on English roads with their short haul and local traffic. Although, when all allowances are made, it still seems clear that American practice is decidedly ahead of English.

Mr. DORSEY said that he had for this reason taken the roads in Massachusetts, which more closely resemble the English roads in length.

Mr. WELLINGTON said that the question was a large one and deserved thorough investigation. Many unfounded claims were made, probably, on both sides. Thus there had recently appeared in the *Engineer*, for the first time, some full statistics upon the question of coal consumption, which shed quite a new light on the large sized claims which were sometimes made of the vastly superior fuel economy of English locomotives. Four of the English roads give their traffic for ten years; the average of those four roads was from 42 to 46, average 43, pounds of coal burned per mile run. In comparison with these figures we have on the Pennsylvania Road, on passenger trains alone, from 43 to 54 pounds per mile, being about 10 per cent higher. It is entirely fair to compare passenger trains here on such a road as the Pennsylvania with the average of both passenger and freight there, because their average weight, even without allowance for the greater speed of passenger trains, would be about the same; and, in fact, on this basis, what difference there was would be slightly in favor of the English locomotives. It was undoubtedly true that American freight engines burned a great deal more coal than the English, but the reason was equally clear, they hauled much more than double the average load per ton mile; the American engine could show far the best record, and while in part it was excusable that the English trains should average less tons, owing to difference in operating conditions, yet in part it was but fair to conclude that it was due to greater efficiency of management, and to better and more durable locomotives. There was no little reason to believe that the combined advantages of the equalized springs and the truck gave the American engines a considerably higher working ratio of adhesion, but that was too large a question to enter into now.

Mr. ROBERT L. HARRIS said that for the purpose of adding to the practical information which is being gathered by reason of Mr. Dorsey's

paper on "English and American Railroads Compared" he recently wrote to his friend, Mr. Andrew J. Stevens, General Master Mechanic of the Southern Pacific Company, at Sacramento, California, asking him, on behalf of our Society, as well as for himself, for some facts about their large engines, and the performance of such machines over the heavy grades of the Southern Pacific Railway near Tehachapi Pass, at which place, in October, 1885, he saw the largest locomotive to which his attention had yet been directed, "El Gobernador."

Mr. Stevens has promptly and kindly sent blue-prints of two of their large engines, one the "No. 229," of the class of 19 by 30-inch cylinders, and one the "El Gobernador," whose cylinders are 21 by 36-inch. He has also sent indicator cards taken on these engines while at work; that on the "No. 229" being taken while hauling 496½ tons (inclusive of engine and tender, 93 tons) up a grade of 105 feet per mile. He has sent a blue-print of the profile of the railway from Los Angeles to Sumner, showing "the grades over which the engines above referred to are running, and upon which the tests below reported were made." The profile shows a division of 168 miles long of heavy grades, much of the distance being on gradients of 116 feet to the mile. "The division is a succession of ten-degree curves."

The two large engines mentioned were built at the Central Pacific Railroad shops at Sacramento, California; the "No. 229" in 1882, and "El Gobernador" in 1883.

The total length of engine and tender, "El Gobernador," is 65 feet 5 inches.

Mr. Stevens states that "these engines are easy on the track, and not expensive to maintain for such large engines performing such heavy service." The following is Mr. Stevens' statement showing the performance of these engines compared with the ordinary 10-wheel 18 by 24-inch cylinder 40-ton locomotive working upon the same division:

"Comparative statement of 18 by 24-inch 10-wheel (6 wheels coupled) 40-ton engine; 19 by 30-inch 12-wheel (8 wheels coupled) 61½-ton engine; and 21 by 36-inch 14-wheel (10 wheels coupled) 77-ton engine, drawing freight over the Los Angeles Division of the Southern Pacific Company between Sumner and Los Angeles:

Number of Engine.	Gross Tons to Train.	Miles to 1 Ton of Coal.	Wages of Engineer and Fireman.	Total Cost.	Cost per Ton per Mile.
18 x 24	220.25	20.77	.0740	.4678	.002124
19 x 30	378.58	16.88	.0814	.5345	.001412
21 x 36	595.33	13.81	.0851	.6351	.001067

"Cost of coal \$7 per ton of 2 000 pounds."

"The gross tons hauled by these engines as mentioned in the report were arrived at from special tests for a given period." Mr. Stevens, however, states "that these engines are daily doing the same work as shown in the statement, and are giving excellent satisfaction."

It will be seen that, according to the report, the cost per ton per mile is with the heavy 77-ton engine only one-half of what it is with the 40-ton engine.

Can the above performance be excelled by any road with equally heavy grades and severe alignment?

If not, then the Pacific Coast may lay claim to having built, under Andrew J. Stevens, Master Mechanic, the best performing locomotives for heavy service. According to the memoranda by Arthur Brown, Superintendent of Buildings and Bridges of the Central Pacific Railroad, read at our last meeting, the Pacific Coast has also built the largest railroad ferry transfer boat.

The above data are from the standpoint of the mechanical engineer. It is desirable to have the views of the civil engineer of the road as to the opinion that such heavy engines "are easy on the track," for we might learn that the reduced expense of the engine service may be somewhat canceled by the increased cost of road-bed, bridges, tracks and their maintenance. The "blue prints" mentioned herein are presented to this Society in the name of Andrew J. Stevens, of Sacramento, Cal.

Mr. ROBERT L. HARRIS, at a subsequent meeting, said that further information in regard to the large engines mentioned had been received from Mr. A. J. Stevens, as follows.

	Engine No. 229.	Engine No. 237.
Gauge.....	4 feet 8½ inches.	4 feet 8½ inches.
Actual weight in working order, exclusive of tender.....	123 000 pounds.	154 000 pounds.
Actual weight on drivers.....	106 050 "	130 000 "
Weight of tender (light).....	32 000 "	33 000 "
Weight of tender, including fuel and water.....	63 000 "	63 000 "
Weight of locomotive and tender in working order.....	189 000 "	217 000 "
Cylinders.....	19 by 30 inches.	21 by 36 inches.
Driving-wheels, four pair, coupled.....	55 inches diameter.	57 inches diameter.
Total wheel base.....	53 feet 1½ inches.	52 feet 7½ inches.
Driving-wheel base.....	15 " 9 "	19 " 7 "
Rigid-wheel base.....	9 " 9 "	14 " 7 "
Boiler, steel, ⅞ inch thick.....	54 inches diameter.	56 inches diameter.
Height of center line of boiler above rail.....	6 feet 8 inches.	6 feet 11 inches.
Fire-box.....	9 feet long by 34 inches wide inside.	10 feet 6 inches long by 34 inches wide inside.
Combustion chamber.....	52½ inches long.	50½ inches long.
Tubes.....	166, 2½ inches by 12 feet.	178, 2½ inches by 12 feet.
Heating surface fire-box.....	118.8 square feet.	197 square feet.
Heating surface flues.....	1 076.7 square feet.	1 154 " "
Tank capacity.....	3 000 gallons.	3 000 gallons.
Steam ports.....	1½ by 14 inches long.	1½ by 16 inches long.
Exhaust tips (two).....	4 inches diameter.	4½ inches diameter.

The above figures are actual dimensions, weights, etc., and may vary slightly from the figures in the blue prints, which were made from estimates while the engines were under construction.

In regard to the last paragraph of the preceding remarks, Mr. W. G. CURTIS, M. Am. Soc. C. E., Superintendent of Track for the Southern Pacific Company, says:

"On a track built especially for such engines, with seventy-six pound rail, large ties closely spaced, good ballast under the ties, and steel rail of best quality, so that the pressure on the smallest possible area of wheel and rail in contact shall not approach the elastic limit of the metal; and, moreover, if water is used as a lubricant between rail and wheel flanges, and will accomplish what is claimed for it, I should say decidedly that the cost of maintaining track under any given amount of traffic hauled by the large engines should not exceed the cost of keeping up the road under ten and twelve wheel engines of the ordinary type."

The rails now in use are fifty-pound steel; the ties are red-wood, not too large nor very close together.

T. C. CLARKE, M. Am. Soc. C. E., said that a comparison of the cost of motive power on the elevated lines of New York with that on the underground lines of London may be interesting, as another example of the correctness of the position taken by Mr. Dorsey.

The statement is taken from the report of the Manhattan Company to the State Engineer for 1884, and the reports of the Metropolitan District lines of London for the same year. The money is given in English currency in both cases.

Receipts of the London underground lines were £1 012 000; expenses, £434 000; leaving net, £578 000. Number of passengers carried, 114 500 000. Cost per passenger $\frac{1}{10}$ d.

Receipts of New York elevated lines, £1 345 000; expenses, £777 000; leaving net, £568 000. Number of passengers carried, 97 000 000. Cost per passenger $1\frac{2}{10}$ d, or more than double that of the London lines.

Hence most persons have assumed that the London lines were worked more economically than the New York elevated lines, all of which confirms the truth of the wise man's remark: "There is nothing so fallacious as facts—except figures."

The truth is this: The trains of the New York lines, owing to the light traffic on the Second and Ninth Avenues, and to the heavy traffic of morning and evening being in one direction only, have to travel four times as far as the London trains do, owing to their traffic being concentrated all around a circle and inside of it.

The train mileage of the London lines for the year above given was 1 647 000 miles, while that of the New York lines was 6 057 000 miles. The receipts per train mile run on the London lines was 18s.; cost, $5\frac{2}{10}$ s.; net, $7\frac{7}{10}$ s.

The train mileage on the New York lines was 6 057 000 miles; receipts per train mile, $4\frac{1}{2}$ s.; cost, $2\frac{3}{4}$ s.; net, $1\frac{3}{4}$ s. Hence it appears that while the receipts per train mile of the London lines was nearly three times as much as on the New York lines, the cost per train mile (which is got by dividing the total working expenses by the total train miles run) was less than one-half.

The returns also enable us to state the cost of motive power, only omitting cost of maintenance of roadway and stations, and of general expenses.

The London trains cost 3s. 4d. per mile run; the New York trains 1s. 9d. per mile run.

The economy, not only of motive power, but of all expenses of the New York over the London lines, is due to the use of lighter and better designed rolling stock, at slower speeds; as well as—possibly—to better management.

The London underground trains weigh about 140 tons, carry 300 to 330 passengers, and run 18 miles per hour. The New York elevated trains weigh about 80 tons; carry, seated and standing, an average of 300 passengers, and run 13 miles per hour.

The cost of maintenance of the "flimsy" iron structures upon which these trains run, is much less than that of the "solid road-bed" of the underground lines.

Finally, if the cost of motive power and train service on the New York lines was as great as that on the London lines, the receipts would not be sufficient to pay running expenses.

WALTON W. EVANS, M. Am. Soc. C. E., said, by letter, quoting from Alexander Von Humboldt, that "the chasms which divide facts from each other are rapidly filling up; and it has often happened that facts observed at a distance have thrown a new and unexpected light on others nearer home, which had long seemed to resist all efforts at explanation."

Mr. Evans, continuing, said that the paper of Mr. Dorsey is one that deals with a subject of vast importance to railway interests. This subject was handled by Dr. Lardner, more than a third of a century ago, with marked ability, in a work entitled "Railway Economy." Then this great moving power was in its infancy, and but hundreds of millions of money invested in it. Now it has absorbed thousands of millions, and become one of the chief factors in the progress of nations throughout the world. Mr. Dorsey has rendered a signal service to the railway interests of any country by comparing the systems of the two countries which were leaders in this great enterprise, and analyzing the results, first, of cost, and then of operating, through which results could be arrived at and reforms instituted when required. Mr. Dorsey took on himself a labor of no small magnitude when he sat down to

write his paper and bring order out of the chaos of interminable rows of figures. To write a sermon, an essay, or an editorial for a morning paper is mere child's play to tackling the figures that make a table of comparison, when those figures amount to millions of units, and when the hundredth or thousandth part of a unit plays an important part in the result sought for. We have Mr. Dorsey's paper before us, and it now remains with us and our friends, the engineers on the other side of the Atlantic, to examine it lynx-eyed as to the methods by which he arrived at his results, and the correctness of his figures; if these are not correct his results fall to the ground, and lose their influence to become factors in working out railway economy. Mr. Dorsey calls on all engineers to examine his figures, and if they can find errors to point them out. A year and a quarter have passed since his paper was read, and, as far as the writer knows, his figures remain unchallenged. In England, the writer has heard that his figures have been met by assertions, and no proof given or offered. Engineers have nothing to do with mere assertions. Leave them to lawyers, whose business it is to befog a jury and make black appear to be white. It has been told to the writer that a member of the Institution of Civil Engineers asserted at the Institution recently that "American locomotives were short lived," and that they were "cheap and nasty" (a questionable expression, but one much used in England). Another member of the Institution, in alluding to American locomotives, said "they did very well on the rough roads of America, but soon wriggled themselves to pieces if put on the good tracks of England." This man was, no doubt, sincere and conscientious. It is astounding to see what people, not lunatics, will believe when they wish to believe it. A ship that can stand up gallantly in a rough sea, in howling storms, is not going to pieces in a smooth sea, when urged along by gentle breezes. The author of the first remark, if properly reported, should recollect that it is a naughty thing for a man living in a glass house to throw stones. He was the engineer and contractor for two narrow gauge railways at Toronto in Canada, and furnished the rolling stock, all built in England. His brain must have had visions of that rolling stock passing before it when he applied the words "cheap and nasty" to American locomotives. In 1874, Mr. Higginbotham, the Engineer-in-Chief of the English Colony at Victoria in Australia, in his report to his government (a parliamentary document) says of this rolling stock (in describing the Nipissing, 83 miles, and the Toronto, Gray and Bruce Railways, 190 miles long): "The two lines to which I have referred were stocked at first with engines, carriages and wagons built in England, which proved complete failures, and have been replaced by American engines and cars; these are found to work well."

"The rigid wheel base of the English rolling stock had been tried and condemned." "The Master Mechanic (Locomotive Superintendent), who is an Englishman, told me that he preferred American to English

engines and rolling stock for railways in Canada." Living in a glass-house like this one, that was clearly "cheap and nasty," it does not come with good grace for this gentleman to throw stones at American engines. Before taking Mr. Higginbotham out of Canada, let us revert for a moment to what he says in his report on the Grand Trunk Railway, an English line intended to be a model one, and equal to the best in the world (it ought to be, it cost enough). Mr. Higginbotham says: "English engines and rolling stock were tried but had to be abandoned, and the American type adopted." The writer has a letter of Mr. Ross, the Chief Engineer of that Railway, in which he says (after alluding to his English model engines being altered to American patterns): "On the breaking up of the frost we never could keep the English engines on the track, except at a slow speed which defeated our object."

In reviewing this paper of Mr. Dorsey's, and looking at the tremendous differences he makes in comparing the railways of England with those of America as to economy in operating, it is clearly the locomotive we must look to as the prime factor in working out this problem, and getting at the astounding results put down to the credit of the American system. There is no use in meeting a question of so much importance to the world with sneers or assertions that American railways are "cheap and nasty," or say that their engines are "gingerbread peacocks," that "wriggle themselves to pieces on a good road," and that "they are here to-day and gone to-morrow." Assertions are not arguments, we give facts and figures, and we wish them controverted by facts and figures, or their correctness admitted. The splendid results shown in Mr. Dorsey's paper, when comparing the American with the English system, appear at first sight to be entirely the work of the locomotive. The writer begs to say that a part of these results belong to the American system of cars; long cars resting on two four-wheeled bogies having chilled cast-iron disk wheels, the safest and most economical wheel ever put under a railway car. This has been admitted by eminent English engineers, among them Sir Douglas Fox, Cor. M. Am. Soc. C. E., in his paper on the Pennsylvania Railroad read at the Institution of Civil Engineers. Another point of merit in the American car is the use of oil in the journal-boxes instead of grease. Mr. McConnell, Locomotive Engineer of the London and North Western Railway, tried a set of six American boxes on the tender of a locomotive, and six English boxes at the same time, for four months, and showed that while the American boxes averaged a cost of 1½d. a day, the English boxes cost 9d. a day. See paper read by Mr. Hodge before the Institution of Mechanical Engineers, October 27th, 1852, at Birmingham. Let any one apply this little economy to a rolling stock of 50 000 cars and 2 500 locomotives and see if it does not amount to something in a year. The greatest merit the American car has, when compared with the English, is its being mounted on eight wheels, while the other rests on four

wheels only. In running these latter, the whole car and its load feel every inequality of the road, and oscillate in the direction of its length, and by so doing render null a part of the power of the engine. In the other case the bogies feel the inequalities of the road, but the body and the load do not, and run with great steadiness. In corroboration of this the writer quotes from a report of J. Boyd Thompson, Manager of the Northern Railway of Buenos Ayres, to his Directors in London, dated June 27th, 1867. "Our stock of carriages consists of ten made in England and two in the United States. During the past ten months repairs to English carriages amount to \$4 086 currency each, whilst during the same period the American carriages have cost nothing for repairs, and are at present in better condition than those made in England, though they have been in constant use since the line was first opened. I may also remark that their chilled-iron wheels scarcely show any perceptible wear. The American carriages are in every respect better and more comfortable, requiring less than one-half the power to propel them that is necessary for the English." It has been proved that the English carriages are much more injurious to the permanent way and works, and likewise in proportion more injurious to themselves than those of American make. "I most strongly recommend the American model carriages and wagons. They cost less, are not so expensive to keep in repair, run easier, and cause less wear and tear on the permanent way." There, that's pretty liberal coming from a Scotchman. He clearly did not think the American cars "cheap and nasty."

Before leaving the Central Argentine Republic, the writer desires to put on record a line or two about the Central Argentine Railway, built by Messrs. Brassey, Wythes & Wheelwright, of London. They sent to the writer for the whole rolling stock required. The carriages and cars asked for were sent out. The locomotives could not be sent, as the engine works were all engaged by the Government, as we were in the midst of our civil war. Some time after, when this railway was nearly completed, Mr. Wheelwright, in writing from Rosario, said, in a lamenting tone: "You would have saved us a mint of money if you could have sent us American engines." It is clear he did not think American engines "cheap and nasty."

This railway, 243 miles long, was over the pampas, and nearly level and straight for the whole distance.

This superiority of the American railway rolling stock is not a new subject for discussion, as it has been talked about and written about ever since the earliest dawn of the railway era. Its merits were soon talked of in England, and, as early as 1837, Norris & Son, of Philadelphia, were called on to build seventeen locomotives for the Gloucester and Birmingham Railway. They gave satisfaction (it was before the time when American engines were called "cheap and nasty"); other orders followed, but the builders in England grew excited and obtained from the

Lords of the Treasury an order prohibiting the importation of locomotive engines into England. The history of this is to be found in the *United States Magazine* for June, 1855.

In 1849, Mr. F. Passavant, an English engineer, came to the States to study the American engine. On returning he published a series of articles on the American locomotive in the *Glasgow Practical Mechanics' Journal*, Volumes 2 and 3, which are interesting. He appears to have grasped at once all the main points of merit in the American engine, and admits them as freely as any American could do. He compares an English slab-frame and an American bar-frame, and shows that the latter is practically and scientifically the best in proportion of 4 088 to 15 232. He describes the merits of the bogies and the use of outside cylinders, and gives his reasons. He says: "In their frame the Americans have successfully attempted to give steadiness, stability and durability to their engines. The above three virtues are solely dependent on a sound, well constructed frame."

"On most English railways, experience has shown that the resistances on a level are twelve pounds per ton. In the United States the resistances appear to be not more than three pounds per ton." [Extract from Mr. Isaacs' paper on "Locomotive Power," in *American Locomotive Engineer*, December 3d, 1858.]

In 1880, Mr. Higginbotham, Engineer-in-Chief for the Colony of Victoria, Australia, in a letter to the writer says: "The Rogers' engines you sent us have done and are still doing splendid work. They are hardly ever in the shops for repairs, are as easy to ride on as a first-class carriage, and are certainly lighter on the permanent way than any other engine which we have. If they had been built here their merits would have been loudly proclaimed, but as they were not, nothing is said about them, and so profound is our provincialism, that any one who published their merits would almost surely make himself unpopular." In 1877, Mr. Higginbotham sent the writer a full account of all the engines on the Melbourne and Woodend Railway, 97 miles long. This shows that the American engines averaged $2\frac{1}{4}$ pounds less fuel per train-mile than the English engines. They were built for passenger service, but as soon as they got them they were put on goods service. These engines have recently been put in repair and are reported as the best engines in the colony to run the new express from Adelaide to Melbourne. Before Mr. Higginbotham came here in 1874, a son of the first Governor of Victoria, in a letter to the writer from Melbourne, said: "Mr. Higginbotham has started by order of this government to visit the railways of the United States. He has his mind made up against all things American."

In 1854-55, the writer directed the building of a branch of the Copiapo Railway, in Chili, for a London company. It ran to the rich silver mines in the district of Chauar Cillo. It had a summit of 4 467 feet,

the highest then known. It had gradients of 5 per cent., and curves of 500 feet radius. The engines were built in England, had bogies and three pair of driving wheels. In discussing "Steep Inclines and Sharp Curves" at the Institution of Civil Engineers, these engines were referred to as giving great satisfaction on account of their having bogies. Now, the fact is these engines sunk the entire capital of that company in nine years, and they had to sell out to the Copiapo Railway Company.

In a private letter of Mr. P. Gould, the Locomotive Engineer of the Copiapo Company, to Mr. Hudson, Engineer of the Rogers Locomotive Works, he says: "Your two last engines are working successfully on the grades of the Copiapo Extension Railway. There was much talk about the fuel burnt. I was afraid the men might be mistaken about the weight of the coal used, and did not say anything to you about it. Now, however, after three months' experience, we are satisfied that we can haul 50 per cent. more load with 20 per cent. less fuel per mile than the English engines." This is much more than I expected. "The difference between these engines is that the old engines have ruined the English company who owned the line before, they having sunk the entire capital, while our engines are making it a very good business for this company. It is true that we bought the line for a very low price; but even at the price it cost the other company it would have paid a fair interest."

In 1869, Mr. Zerah Colburn, by request, read a paper, No. 1230, before the Institution of Civil Engineers, on "American Rolling Stock." In a letter to the writer he asked for some data on the subject. The writer sent him a good deal, and then told him: "You will not dare to get up in the presence of any body in London and give this as I give it to you, for your bread and butter is, in a measure, mixed up in this matter." Mr. Colburn did not give the data I gave him, but contented himself with saying that the chief differences between American and English rolling stock was a matter of "toilet." In his paper he describes running a test train over the entire line of the Erie Railway to get at the engine power required on each division. In the discussion that took place on this paper Mr. Berkely doubted the correctness of Mr. Colburn's figures, as he thought no engine ever made could give such results.

The *Engineer*, of London, in speaking of engine trials made under the direction of the writer on a government railway in Chili, in 1859, said that such results had never been obtained by any engine, and never would be. In a discussion on the economy of fuel at the Institution of Civil Engineers Mr. Lloyd, in referring to the Chili trials, said that "the English engines showed the greatest economy, as proved by Mr. Evans' experiments." The fact is that these trials proved the reverse, and Mr. Lloyd should have known it, for the locomotive engineer of his road was on the engines all four days of these trials, taking notes, which were like mine.

The Tongoi Railway, on the coast of Chili, has in it, on the summit division, gradients of 1 in 20. This road was originally stocked with engines and cars from England. It is owned chiefly by Englishmen. In 1870, Mr. Green, the Manager, sent to the writer for some American engines to work his steep inclines. After these engines were sent out he was asked to give some relative data in reference to the performance of these engines with the English engines. He wrote, "I cannot give you what you ask for, as I am now doing all the work on the summit division with the Campanil, one of your engines, where I formerly occupied the services of two."

Mr. J. C. Hoadley, a mechanical expert of high standing, was sent to England in the midst of our civil war, to procure guns for the defense of Boston harbor. He was delighted with all he saw, Scott Russell and others having been very kind to him, showing him the railway works. He said to them, "Gentlemen, this is all very magnificent, but it is also very extravagant. We cannot afford such expenditures as I see here on all sides. If by some great convulsion of nature we in America were to lose all our rolling stock, and you, in the generosity of your dispositions and kindness of heart, were to offer to replace it as a gift, we could not afford to accept it."

In the centennial year, Mr. Massey Bromley, of the Great Eastern Railway, was sent here to study American locomotives. The writer gave him letters of introduction. After spending three months in the study he came for, he came to the writer's office and said, "I am delighted with all I have seen, and am going home to build American locomotives." The writer said, "Will you build American driving wheels?" He said, "Yes, as I find them better and cheaper." Being asked if he intended to build American frames, he said, "No; your frames are too expensive, we cannot afford them." The writer replied, "You will not have an American locomotive, for the frame is the backbone, one of the chief points of merit on the whole machine."

In 1877, the writer sent two patterns of engines, by order of the government of New Zealand, to their Locomotive Engineer, who was in charge of the motive power of more than one thousand miles of railway. He, during two years, in many letters, spoke in the highest praise of the merits of these engines, saying, "They are doing wonderful work; day after day they are turned out to run the express at thirty miles per hour on forty-pound metals, and never a hitch takes place. They keep time and work cheaply, and the men who drive them all maintain that they are the best engines they have ever been on. We are running the American engines imported for the Rakia and Ashburton Railway, and find them the most steady and smoothest-running engines in the country. I have much pleasure in informing you that the Baldwin engines are doing first-class work. About ten days ago, one of these hauled the heaviest train ever moved by one engine in this colony. It

consisted of one hundred and eight wagons, loaded, and was estimated to weigh one thousand tons. The train was within one hundred feet of half a mile in length; speed, twelve to fifteen miles per hour; coal, native lignite. These engines are making a name for themselves. I should not be surprised to see American engines entirely adopted in this country. The Rogers passenger engines work splendidly. They are making each forty thousand miles per year. The more I see of American engines the more I like them. In the long run, the American engines will prove their worth to the most prejudiced mind. I used them on all the bad roads. They run over roads that would destroy our heavy English engines in three months."

The standard gauge of New Zealand is 3 feet 6 inches.

Mr. James Hall, an English engineer of great ability and standing, director and manager of the motive power of all the government railways of Chili, has been ordering American locomotives for about twenty-five years. In writing for more engines, in 1882, he says: "You will notice that I recommend more powerful engines than the old 14-inch cylinders. On this section we have long grades, and a heavy traffic always up. Our passenger trains consist of twelve American coaches (equal to twenty-four English coaches). It is only just to the old engines of the class Tano, cylinders, 14 by 24, wheels, 63 inches, to say they have done their work admirably, and are as good and as economical as you will find in any part of the world. The Tano ran nearly one hundred thousand miles without requiring any repairs worth mentioning."

Mr. J. L. Stothart, a well-known English engineer, who has been connected with railroad building in England, and who is a member of the Institution of Civil Engineers, came to this country in 1883 to see our railways and the machinery used in working them. On his way home he wrote a letter to Mr. Robert E. Pettit, M. Am. Soc. C. E., Manager of the New Jersey Division of the Pennsylvania Railway, thanking him for permission to ride on the engine, in which he says:

"Freedom from Oscillation.—In this respect, and the principal one, I wished to satisfy myself upon, your engines leave nothing to be desired. They are absolutely steady at the highest speed, and upon carefully gauging the framing with the rail, I could never detect any oscillation on a straight track, whatever speed was obtained. On the journey from Trenton to Jersey City on No. 260, we ran three consecutive miles in 58 seconds each, and two miles in 1 minute 58 seconds. There was no swing on the engine at this speed, and I do not think any English locomotive at these speeds would have been so free from oscillation.

"General Working Arrangement.—In this respect your engines are perfect. All the handles are brought to one focus, and the introduction of steam reversing gear demands no manual exertion on the part of the drivers. The engines run nearly as comfortably as your carriages."

In the *London Engineer*, of October 1st, 1858, the editor says: "Mr.

Robert Stephenson stated, while in America, that the engines in that country were better than those of English build, while the same gentleman, to the knowledge of the writer, has reiterated the same opinion within the last ten days."

In September of last year, Mr. D. Banderali, engineer of the motive power of the Northern Railway of France, came here to study the American locomotive, and in May, in a French review on railways, gives an account of some of his observations. He says he "was struck by the fact that the number of locomotives was small in proportion to the mileage of the road and the train mileage, and also by the fact that so small a portion of the engines were undergoing repairs in the shops; also by the smallness of the stocks of materials used for repairs. The repairs of the locomotive are reduced by the solidity and simplicity of their construction. One remarkable fact prevails everywhere, and whatever the system adopted, I have found the engines in a perfect state of repair, and the motive power service as satisfactory as possible.

"It is not without difficulty that the American engineers have succeeded in modifying established customs. Their personal intervention, energetic, patient, persistent, at the same time adroit, action, has overcome all opposition." Longer quotations from this paper might well be given, it is all very interesting.

In 1883, the Minister of New Zealand ordered twenty locomotives in England, sending drawings and specifications. At the end of eighteen months he heard of two being finished and ready to ship. The Agent-General informed him that as these engines weighed each ten tons more than the contract called for, he had better strengthen all his bridges, or they would break them down. Wishing engines badly, he ordered twelve of the Baldwin Locomotive Works in Philadelphia. They were all completed and shipped in three and one-half months. The Minister then said in his report to Parliament: "The best of this business is that these engines will cost, delivered here, £400 each less than the English engines."

In 1852, Mr. Edward Woods, a distinguished engineer of England, at present President of the Institution of Civil Engineers, was called by the London and North Western Railway Company to examine and report on the causes for the very excessive amount of fuel consumed on the Southern Division over that used on the Northern Division. After great labor during more than a year, and after equating the cost of everything that could be equated, they found a large amount unaccounted for, except by the use of large inside-connected engines on the Southern Division over the amount burned by the smaller outside-connected engines of the Northern Division.

Mr. Woods did not find that it was the largest amount of fire surfaces in an engine that always produced the largest amount of steam, nor did he find anything to prove the inferiority of the outside-connected en-

gines of the Northern Division on a single point, nor did he find that inside-connected engines were always steady running engines.

In a recent letter to Mr. Woods, the writer mentioned having read Mr. Stroudley's paper on his new design for engines, and said it looked to him as if they were going backwards in engine construction in England; and he thinks from the remarks made by W. H. Mills, of the Great Northern of Ireland, in the discussion, that he supports him in his views. To build engines with crank-axles makes the center of gravity exceptionably high, and then to place the driving wheels as leading wheels, and claim these points as merits in engine construction, is to American engineers incomprehensible.

The London *Railway News*, of November 16th and 30th, and December 7th, 1872, and February 22d, 1873, published some very interesting statistics of comparisons between four English and four American railways. They are too long to go into a paper of this kind. One of these comparisons may be mentioned. After stating that the business of the New York Central Railway was greater than that of the London and North Western Railway, it shows that the former is worked by $\frac{5.0}{1.0}$ of a locomotive per mile of road, while the latter occupies the services of $\frac{1.0}{1.0}$ engines per mile of road.

The writer has now mentioned the opinions and writings of many clever engineers, most of them Englishmen, and has probably given a hundred times more than is necessary to convince any unprejudiced mind that there is not only merit, but great and wonderful merit in the American engine. But if their writing had extended to a thousand times as much, it could not have convinced any one of those who are blinded by prejudice and who are skeptics as to anything good having originated in America. The writer is inclined to think that if that great man, George Stephenson, that great master of mechanical instinct, should come up from the tomb to see the railways and judge of the progress that had been made, by the money results, and comparisons in different countries, particularly those of England and America, he would shrink back in holy horror.

It is generally believed that a first-class railway in all its appointments, should be able to carry vast amounts with regularity and speed, without accident and without straining any of its parts. Let us glance at a few things that have been done in America, and see if they have ever been matched in any other country.

In the Centennial year a train was run from New York to San Francisco, a distance of 3 317 miles, in 83 hours and 27 minutes actual time. This is nearly forty miles per hour for the whole distance. This train passed over four mountain ranges, one with a summit of 5 100 feet. On the Pennsylvania Railroad Division this train was run at a speed of 43½ miles an hour crossing the Allegheny Mountains, total distance being 439½ miles, and without making a stop. Mr. Howard Fry, an

English mechanical engineer, Locomotive Superintendent of the Philadelphia and Erie Railroad, October 27th, 1877, ran a train of 100 eight-wheel cars loaded with coal oil and grain, weighing 2 201 tons (2 240 pound tons); length of train, 3 127 feet; speed of train, 10½ miles per hour; engine No. 41, cylinders 20 inches by 24 inches; weight on drivers, 88 000 pounds; road approximately level. This engine ran 26 trains in this month, with from ninety to one hundred and six cars in each train.

The Reading Railroad of Pennsylvania, which transports much the largest tonnage of any railway in the world, in 1885 carried as follows:

Passengers carried.....	23 531 057
Coal carried in 2 240 pound tons.....	12 530 594 tons.
Merchandise carried in 2 240 pound tons.....	7 493 510 “

The coal trains in summer are made up of 125 cars, and in the winter 115; average coal carried per train, 800 tons. A train on a branch of this road to New York, May 9th, 1884, ran 10 consecutive miles at an average of 75 miles per hour; work of this kind could not well be done by railway machinery that was “cheap and nasty.”

On August 18th, 1886, a special newspaper train, No. 11, was run on the New York Central Railroad from Syracuse to Buffalo, 148½ miles, at average speed of 65½ miles an hour. On one section of ten miles the speed was 75 miles per hour. This engine had made her regular trip of 300 miles the day before, and did the same the day after.

Mr. DORSEY, in closing the discussion, said that Mr. C. E. Goad was very much mistaken in saying that the English passenger cars, by means of their side doors, can be unloaded and loaded in one-third the time that the American cars can through the two end doors.

Mr. Dorsey had personally taken the time of 531 stoppages on trains running into and in London, and 342 stoppages on trains on the four elevated railroads in New York. In all cases all stoppages that were prolonged by block signals, loading baggage or other causes, not caused by loading or unloading passengers, were rejected. The average of the 531 London stoppages was thirty-three and one-third seconds, the average of the 342 New York stoppages was eleven and two-thirds seconds—nearly one-third.

On the London roads the shortest average stoppages were made on the Metropolitan Railway. Theoretically, eight or ten persons should be able to leave or enter a car by one door quicker than fifty persons can by two doors; practically it is not so, as much time is lost by the passengers in finding among the six kinds of carriages on the London trains, the particular kind he or she wishes to ride in. After this is found, much more time is lost in opening doors and looking for a seat, whilst in the American cars there is only one class or kind, the passengers can enter by any door and find seats after the train is in motion.

He considered that Mr. Goad's remarks about lavatory conveniences on the cars used in the United Kingdom were very misleading. It is true some very few of the first-class carriages have water-closets. The Board of Trade Reports for 1884 show that only five per cent. of the whole travel of the United Kingdom was first-class. It is safe to say that not one per cent. of the first-class carriages used there have these conveniences, thus giving this great comfort to only about one person in every two thousand. This is very hard on the majority of travelers, who have no other fault, except being poorer than the few richer or more privileged ones, nature giving to all alike the same necessities and requirements.

Mr. Dorsey fully agreed with Messrs. Collingwood and Shinn that all crossings in populous sections should be either above or below the level of track, whether at stations or any other place. In his paper he advised that laws should be passed compelling this to be done. He would advocate passing laws obliging all crossings, whether for vehicles, animals or foot passengers, to be either above or below grade in all counties or townships where the population averages over forty persons to the square mile.

Few persons have traveled more in the United States and England than himself, and after all this experience he is a firm believer in our check system for baggage.

Recently the London and North Western Railway made arrangements to check baggage from England to New York. Last month he had his baggage checked from his apartments in London to New York by this system, with very satisfactory results, as it enabled him to stop over between London and Liverpool without being troubled to look after his baggage, which he found all right on the New York dock. The railway company gave a slip of paper instead of our brass check. A receipt was given for the baggage when delivered in New York.

In regard to Mr. Goad's experience with his baggage, the remedy is very simple. If he or any one else prefers the English system, they can easily follow it here. There is no law obliging them to patronize the baggage expresses or transfer companies, all are at liberty to follow the English system if they prefer it, and take their baggage in a carriage to and from our railroad stations.

Heretofore all the discussion on the check system has been from the travelers' standpoint, as effecting his comfort and convenience. In the opinion of the author, the English railroad companies are more directly interested in this than the passenger, as by adopting it they could decrease their station expenses largely. He had many times counted over forty porters engaged in loading the baggage at one time, while at the same time many others were occupied on other platforms, especially in unloading the baggage from arriving trains. There must be in some of the large stations in England several hundred porters thus employed.

Over eighty per cent. of these could be dispensed with by adopting our baggage check system, as most of the work they perform is done in the United States by the baggage express companies without cost to the railroads. It is true the porter's pay is very small, about 18 shillings (\$4.37) per week, but in the aggregate it must be quite a respectable sum, and of sufficient importance to save.

In reply to Messrs. J. F. Crowell, M. N. Forney, A. M. Wellington, and W. H. White, Mr. Dorsey stated that it is absurd to compare the cost of train miles in the two countries, owing to the American train averaging so much heavier loads than the English. For example, on the Pennsylvania Railroad Division the average load is three times larger than it is on the London and North Western. In comparing the cost per train mile the average load must be considered, or the comparison is false and misleading.

Mr. Dorsey again repeated that the English railroads make no return of the ton or passenger mileage, nor do they separate the cost of freight or passenger traffic.

He had made a great many inquiries in different places; the prevailing rates over different roads were ascertained; and then, by taking the percentage of each class of passenger and freight, the rates, as stated on pages 16 and 735 of his paper were adopted.

Since they were first published and discussed, eighteen months had elapsed without their being disputed in any way; but, on the contrary, they have been confirmed from many reliable sources. For example:

The *Engineering*, of London, of August 20th, 1886, page 187, in speaking of "British Railway Administration," says:

"The average receipts from goods traffic in 1885 were only about 2s. 9d. per ton, and if we reckon that the average ton-mile rate was only 1d.—although it is certainly something more—the average length of lead for goods traffic would come out as thirty-three miles. * * * The train-mile receipt is not a function of the rates and fares so much as of the weight of the train, or rather of the live load carried, and if the English railways will persist in carrying loads of 50 to 100 tons, where they might just as easily carry three or four times that load with very little increase in the main items of working cost, they must expect not only a low range of train-mile receipts, but a low range of dividends as well. * * * And each passenger travels a distance of six miles."

This latter worked out, makes the average passenger fare per mile somewhat greater than the author's estimate, showing that he is conservative in his figures.

The preceding is an unequivocal indorsement of the author's estimated average freight and passenger rates, and also of the estimated train load based upon his rates. It also confirms the views of the speaker as expressed in his different papers, that the English train load

in freight and passengers is too small for economical working, and by making the loads much larger the rates could be lowered, or the dividends increased.

Mr. J. S. Jeans, the able statistician of England, says, on page 181 of his "Annual Statistical Report" to the British Iron Trade Association for 1884:

"The average ratio quoted for the transport of iron ore and coal in England could be varied either upward or downward according to the distance or lead. But if the average rate is taken at 1d. per ton per mile, which is probably as near the mark as we can get, instead of 1.02d. as shown is the average of iron ore."

If the average freight charge per ton per mile on iron ore is 1.02d., and on iron ore and coal 1d., the author's estimate of 1d. average charge per ton per mile on all freight is much too low. If it is too low, the estimated train loads in England are too large, and should be reduced.

Sir B. Samuelson, M.P., in his pamphlet, "Railway Goods Tariffs," 1886, gives a long list of freight charges on many different articles between many different points. These charges have been ably analyzed by Mr. E. P. North, M. Am. Soc. C. E., in his discussion on this paper. See page 766 of this volume. These rates more than confirm the author's estimates.

In the evidence of Mr. Alexander Meadows Rendel, C.E., in the "Report of East India Public Works," printed by order of the English House of Commons, on page 502 he says:

"Assume, also, that the average charge in Great Britain and Ireland for carrying a passenger 1 mile is $1\frac{1}{8}$ d., and for carrying a ton of goods (including minerals amongst goods) 1½d. per mile. I am obliged to assume these figures, because no English company either publishes its average charges, or states its charges in such a way as to allow the averages to be ascertained. The object here is to assume averages favorable to the English lines; that is to say, rather below than above the fact. And I am quite satisfied that in taking $1\frac{1}{8}$ d. for passengers and 1½d. for goods I have done so."

These last are the identical figures arrived at and used in the paper under discussion, as will be seen at page 16.

Mr. Dorsey had seen letters from some of the principal railroad managers of England in reference to his paper, but none denying the correctness of his ton or passenger mileage estimate.

In answer to all remarks about the cost of "repairs and renewals of locomotives," cost of "motive power," "maintenance of way," and "total cost of operating expenses," he referred to his Table No. 45, where thirteen of the principal railroads of the United Kingdom are compared with fifteen representative roads of the United States, all this data being from official sources, except the passenger and ton mileage.

Backed by this strong corroborating evidence, he felt that he could very properly repeat from his first paper: "He hopes that the railroads which are so largely interested in this question, will promptly replace his estimates of ton and passenger mileage by their official figures. Until this is done he claims that these figures should be accepted as correct."

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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(Vol. XV.—November, 1886.)

THE AMERICAN LINE FROM VERA CRUZ TO THE CITY OF MEXICO, VIA JALAPA, WITH NOTES ON THE BEST METHODS OF SURMOUNTING HIGH ELEVATIONS BY RAIL.

By A. M. WELLINGTON, M. AM. SOC. C. E.

READ AT THE ANNUAL CONVENTION, JULY 3D, 1886.

WITH DISCUSSION.

The line described in this paper, and illustrated in the accompanying maps and profiles, is one located by the writer, as consulting and afterward chief engineer, from the Port of Vera Cruz to the City of Mexico, via the City of Jalapa, being a parallel line to the existing Mexican Railway—the first railway built in Mexico—in the sense of connecting the same termini, although following a very different route and of a very different character.

All the features of interest and of difficulty, both in the line here

described and in the line of the Mexican Railway, are confined to the mountain grade by which the necessary abrupt ascent from the level of the sea to the level of the plateau, 8 000 feet above the sea, is accomplished. Once on the plateau there is no great difficulty in going almost anywhere with very light work; many high mountains being scattered around, even on the plateau, but disconnected, with flat lands between.

The elements which appear to make the mountain grade of this line particularly worthy of description are these:

First.—It is believed to be by far the longest continuous grade line ever located; 116.9 kilometers (72.64 miles), having been located on an unbroken 2 per cent. grade (105.6 feet per mile), rising in that distance from elevation 600.4 feet (183 meters) to elevation 7 923.3 feet above the sea (2 415 meters). The accompanying Plate LXXXII shows graphically the extent of the contrast in this respect with some of the other great inclines of the world.

Secondly.—It is believed to be on the lowest rate of grade, by about 2 per cent., ever successfully attempted for accomplishing within a limited distance, either by a continuous grade line or otherwise, a rise of over one-half as much as was attained on this line. The grounds for this belief also are shown in the accompanying Plate LXXXII.

Thirdly.—The line is believed to be, by probably one-half at least, the cheapest line per mile which has ever been actually located, with equally favorable alignment, for attaining within a limited distance as much as one-half the rise actually attained by this line, either by continuous or broken grade lines, on any rate of grade. As for this, Table No. 1, Plates LXXXIV and LXXXV and the general knowledge of engineers is the only evidence that can conveniently be appealed to, or which it is worth while to attempt to present.

Finally.—It appeared that the manner in which the line was obtained might have a certain instruction and encouragement to those who may be dismayed, as was the writer, by having similar problems of unusual difficulty suddenly thrust upon them, and it was also desired to give, in connection with the description of the line, certain conclusions which the observation and experience of the writer has indicated—not only on this incline, but on eight or ten others of considerable rise, which have been located or relocated in part or whole under his supervision, aggregating over 24 000 vertical feet—in regard to the most ad-

vantageous and economical manner of dealing with great inclines, under which may be classed anything exceeding 1 200 to 1 500 feet of vertical rise.

It is one of the unfortunate features of the department of engineering to which this paper refers—that of laying out railway lines to the best economic advantage—that a mere description of a located line has ordinarily little technical interest or instruction, since it is ordinarily impossible to so carefully describe any line on paper as to enable even an intelligent impression to be formed as to the real character of the work. If the grades and work be light, it may be because the line was well laid out, or it may be simply because there were no serious natural obstacles in the way. On the other hand, if the grades and work be heavy, it may be due to bad engineering, and so discreditable; or it may be due to the existence of gigantic difficulties, and so an evidence of skill. It is but natural, however, that the magnitude of the natural difficulties to be overcome should in general be regarded as bearing some nearly constant ratio to the magnitude of the works constructed to overcome them; and hence, that, even when the construction of a very costly line may have been, as a matter of fact, an avoidable extravagance, due to lack of skill or foresight, the very magnitude of the works gives more instead of less reputation to the line as an engineering work.

Only in the comparatively rare cases when two independent alternate lines exist between the same termini, is it possible for the engineer to find in printed descriptions of located lines, however perfectly mapped, any rational basis for intelligent judgment. The present happens to be one of the cases in which this is possible, owing to the existence of the parallel line before mentioned, but in order to avail of it, it becomes necessary to enter somewhat into what would otherwise be an invidious—because unnecessary—comparison with the parallel and previously constructed line. The writer feels the less embarrassed in doing this, as, owing to the checkered history of the line, no one engineer can be held responsible for its character, and there were certain circumstances tending to impede entire freedom of choice and proper investigation.

The whole interior of Mexico is a vast plateau, at an elevation of 5 000 to 9 000 feet above the sea, bounded by an abrupt escarpment from which the descent to sea level is almost immediate. The edge of the

plateau is higher and sharper on the Atlantic than on the Pacific Coast, and at no point on either the Atlantic or Gulf Coast is it higher or sharper than directly in line between the capital of the country, Mexico, and its chief port, Vera Cruz. Here two stupendous natural obstacles, the Pico of Orizaba on the south (17 873 feet high), and the Cofre, or "Box," of Perote (12 500 feet high), both of them described in physical geographies as volcanoes, although both are temporarily extinct, and the two connected by a ridge over 10 000 feet high at its lowest saddle—combine to forbid a direct line inward.

Orizaba is one of the three mountains in Mexico covered with perpetual snow, the other two being Popocatepetl (17 884 feet), and Ixtaccihauatl (15 705 feet), overlooking the valley of Mexico. These, however, start from a plain 8 000 feet high, whereas Orizaba starts practically from sea level on the coast side, making it in that sense by much the highest mountain on the North American Continent,* and among the highest in the world. Its snow-clad peak is visible 60 miles out at sea, long before there is any other evidence of land, and with the morning sun shining on it is a very striking sight. Its last violent eruption was in 1546, soon after the Spanish conquest, although it now occasionally throws out smoke. Only one or two men have ever ascended to its crater, the first one having been Lieutenant Reynolds, U. S. A., in 1848. The line of the Mexican Railway passes to the south of this mountain as shown on Plate LXXXIII.

The Cofre, or "Box," of Perote (so named from a cylindrical basaltic needle about 300 feet in diameter and 300 feet high which caps the mountain, like a box laid on its peak), although formerly one of the most active volcanoes in the world, and classed as still active, is perhaps permanently extinct, its last, and probably also its greatest, eruption having been to form what looks to be, and is in fact, a frozen river of lava, shown on Plate LXXXIV, extending to and running into the sea 50 miles distant, filling up an enormous barranca or deep gulch in the process, in a manner which was very convenient for subsequently carrying the line over it, as may be seen on Plate LXXXIV. The natural variations in the width of this gulch have caused lakes and frozen "water-falls" of lava, which makes it difficult to believe, as one looks up the slope upon

* Mount St. Elias, in Alaska, is a possible exception, being only about 30 miles inland and its height variously given as 14 970, 16 900, 17 850, "over 18 000" (U. S. Census Report) and 19 500.

it from some commanding point, that the mass is not still flowing, making it a unique and impressive bit of natural scenery. Vessels have been frequently wrecked in the toe of this flow where it enters the sea. It has still hardly any deposit of sand, soil or vegetation on it, that and other facts evidencing that the flow is geologically very recent, not antedating much the historic era.

Around the north side of this mountain, and directly over this lava flow, the line here described passes, as shown on Plates LXXXIII and LXXXIV, being about sixty miles north of the Mexican Railway line at its greatest divergence, the two beginning to come together again very soon thereafter. The summit of Perote is just below the limit of vegetation and of perpetual snow, and it is very easily ascended on horseback to the foot of the "cofre," or box, that fact alone being an evidence to the engineer of how different the topography of its slopes must be from those of its southerly companion. Evidences abound of tremendous flows of lava in remote geologic times, which are now covered to a considerable depth with soil, and in the kind of pocket formed between the foot-hills of the two great mountains, in which lie Jalapa and Coatepec, the detritus of ages has accumulated, including probably great amounts of volcanic ash, so that no rock exists over large areas, as was afterwards discovered, except in isolated points.

Cortez followed this route on his first invasion, as did General Scott 328 years later, but from an early date after the conquest of Cortez, two leading routes have existed between the interior and Vera Cruz, following substantially the two railway lines here described, one through Jalapa, rounding Perote to the north, and the other via Orizaba, rounding the mountain of that name to the south. The northerly line was first constructed, and over it, for 300 years (between 1521 and 1812-20) passed vast sums of silver and gold, practically the entire product of the Mexican mines, amounting in the aggregate to \$3 000 000 000, or nearly half of the value of silver in the whole world, which, in 1876, was estimated at \$7 232 071 674; exclusive of what existed before 1520, which was relatively little. During all this time the southerly route was an insignificant trail, but early in this century the southerly route took prominence, and the Jalapa *camino real*, or "King's highway" (as the leading roads are still called in republican Mexico), was suffered to fall into decay. It had originally been paved, guttered and curbed for the entire distance from Jalapa to Vera Cruz, some 73 miles, and from Jalapa up the mount-

ain a fine macadamized road, likewise curbed and guttered, existed, and still exists in fine order, having been recently repaired.*

- Within fifteen or twenty years after the abandonment of the northern highway, as early as 1837, the movement for a railway between Vera Cruz and Mexico was begun by Don Francisco Arrillaga, and very naturally, but very unfortunately, the route which had by that time become the only one generally known, assumed a prominence which it held to the end. The very facts which made it best suited for a highway, that a very comfortable valley ran directly up into the bowels of the mountains, from which the ascent was abrupt and sharp to the plains above, made it unsuited for a railway line, but this could hardly be appreciated at that early day.

By 1854, the construction of a tramway from Vera Cruz had been begun, Don Antonio Escandon, a wealthy Mexican banker, who was chiefly instrumental in pushing the project through to completion, having then taken hold of the enterprise. Don Antonio had a large estate near Orizaba, and his property interests may well have somewhat influenced the final decision. However this may be, in 1857, Colonel Andrew H. Talcott, an American engineer, arrived with a staff of assistants, the only member of which now living, the writer believes, is Mr. S. Wimmer, M. Am. Soc. C. E., then a very young man, after whom one of the leading bridges of the line was subsequently named. According to one of the published histories of the road, all these engineers confined their labors to the Orizaba line, that via Jalapa being entrusted to a Mexican engineer, Don Pascual Almazon. According to other accounts, a commission of engineers examined both lines. If the first was the case, it is less surprising that "on comparing the separate surveys," as the history of the road states, that by Orizaba was finally adopted, on the grounds, first, that there was more traffic to be secured on it (which is rather more than doubtful, although the local traffic at best is an insignificant element), and secondly, that "notwithstanding it requires great and costly works, the line presents greater facilities than that by Jalapa, *where the larger number of ravines and the harder nature of the soil would have required much heavier outlay.*" A greater mistake than is contained in the italicized part of the quotation could not well be.

* On the lower part of this highway a splendid stone bridge, the *Puente Real*, or as now described, the *Puente Nacional*, which has been not unreasonably claimed to be "worthy of the best days of Rome," still exists in perfect order, and as showing the fine quality of the Mexican lime, the joints are considerably harder than the stone itself (which is durable, but rather soft), and are worn less.

Colonel Talcott's estimate of the line was \$15 000 000, but nothing more was done than to build about ten miles of surface line out of Vera Cruz, until August, 1864, when the military necessities of the Emperor Maximilian led to a real beginning and prompt pushing of the work under English engineers, and by an English company, which still controls it. Beyond a statement that the resumption was "after rectifying the plans of Colonel Talcott," the official history contains no record of the second examination of the whole question of route, which was in fact made, although how thoroughly the writer cannot state.

By 1867 the line was opened from Vera Cruz to Paso del Macho, 47½ miles, and from Mexico to Apizaco, 86½ miles, the rails for the latter being hauled by wagons an average of 200 miles inland, at enormous cost, a hard condition imposed by the Mexican government. A third change of engineers took place about this time, while the heavier parts of the work was still unexecuted. In 1868, the Puebla branch, 29 miles, was opened, the rails for it having been hauled in the same manner. In 1870 the line was opened to Atoyac, 54 miles from Vera Cruz; in 1871 to Fortin; in 1872 to Orizaba, and on the last day of that year the entire line was opened with great ceremony.

Shortly thereafter, in 1884, Don Ramon Zangronez, of Vera Cruz, succeeded in getting a branch line to Jalapa well under way, and in having it assumed by the Mexican Railway, which completed it, as shown on Plate LXXXIII, in May, 1875. It is operated solely by animal power, being probably by far the longest horse railway in the world. Its grades are very severe (10 per cent.), and its curves of ordinary horse-car radii. It is laid for a great part of its length along the old *camino real*, and exhibits the same trait as the main line of the Mexican Railway to the foot of the mountains, that is it runs obliquely across the drainage lines, thus materially increasing the difficulties of both lines, but making the Jalapa line absolutely impracticable for an ordinary railway, even with gigantic work. It was probably some such erroneous treatment of the lower part of the descent which led to the condemnation of the route, as it seems impossible that an ascent from Jalapa on a 4 per cent. grade could have been deemed as serious as that from Orizaba on the adopted line.

The main line thus constructed is still one of the most massive and costly in the world. Its cost was abnormally increased by two causes: First, the political condition of the country, which was so much disturbed

that it no doubt added much to the cost; and secondly, the absurd requirement that construction, including track-laying, should begin from both ends at once, necessitating the enormous expense referred to for hauling rails over execrable roads from Vera Cruz to Mexico and Puebla. In all some 15 000 tons of rails were thus hauled, at a cost, the writer believes, of some \$80 per ton, amounting to some \$1 200 000 in all. On the other hand, there was little direct inflation of the capital account, most of the share capital representing actual money paid in. The gross nominal cost of the line was as nearly as may be, \$40 000 000. Reducing this by one-half, we shall make an ample allowance for the effect of all abnormal causes tending to increase cost of line, and for the cost of the Jalapa horse railway and the small amount of rolling stock (65 engines, 810 cars), leaving \$20 000 000 to represent the actual cost of 264 miles of main line and 29 miles of branch. Of this the section between Paso del Macho and Boca del Monte alone, some 60 miles, is in any sense difficult or costly work. The remaining 223 miles is light work, with $1\frac{1}{2}$ per cent. grades, which latter are quite unnecessarily high.

On this basis we may distribute the actual cost (taken at half the nominal) about as follows:

223 miles light work, at \$40 000 per mile.....	\$8 920 000
60 miles very heavy work, at \$184 667 per mile....	11 080 000
283 miles in all, at \$70 670 per mile.....	\$20 000 000

Both the grades and curves on this line are very severe. Only 10 miles out of Vera Cruz 1.5 per cent. grades begin, which shortly thereafter are increased to 2 per cent., 2.5, 3, and at last to 4 per cent., which latter is entirely unbroken for the last 13 miles of rise, and used also at several other points on the ascent. Curves as sharp as 325 to 350 feet radius (16 degrees 30 minutes and 17 degrees 40 minutes) are used, and six or eight reversed curves of these radii often succeeding each other without any tangent between them, and without any grade compensation, making the virtual gradient fully 6 per cent. Fairlie engines are used to operate this grade between the summit at Boca del Monte (107 miles from Vera Cruz) and Cordova. The remaining 157 miles to the City of Mexico, as well as the lower and easier part of the mountain grade (which, however, has $2\frac{1}{2}$ to 3 per cent. grades, increased by unreduced curvature), is operated by American engines. Very naturally both the freight rates and the expenses are fabulously high,

receipts ranging from 10 to 12 cents per ton mile, and as high as \$8 per train mile; expenses being from 50 to 60 per cent. of receipts. To show how radically the cost and revenue from the operation of this line differs from anything with which we are familiar, it was calculated in 1883 that with the Mexican rates the New York Central would earn \$27.25 and the Erie \$28.50 per freight train mile, and their total freight earnings would have been in one year \$297 025 000 and \$244 300 000 respectively—\$168 000 000 more than the Central's whole capital account, and \$93 000 000 more than the Erie's.*

There are fourteen tunnels in all on the line, none of them, however, very long, and about as many viaducts. The grading is, for miles together, almost wholly rock, and the work, as a whole, can only be described as Titanic, so that it is small matter of surprise that almost every one who writes about the line describes it in much the same terms as does Mr. George William Curtis in a late number of *Harper's Magazine* (February, 1886), who chances to be the last writer whose remarks in respect to it have come to the writer's knowledge.

"If it is magnificent scenery that you seek, here at hand, with no intervening ocean, is the railway from Vera Cruz, 260 miles, to the City of Mexico—a marvelous feat of scientific skill, crossing the mountains at a height of 8 500 feet, and bearing you through every climate, amid unimaginable luxuriance and brilliancy of vegetation, changing into temperate hues of hardier growths, with awful mountain abysses between and snow-clad peaks beyond against the deep blue sky."

The line located by the writer rises to almost precisely the same height of summit as the Mexican Railway, and is as nearly as may be of the same length, but in almost every other detail stands in broad contrast with it, thus:

GRADE.—Continuous 2 per cent. (uncompensated) against a broken 4 per cent. (uncompensated); including the effect of curvature or of compensation therefor, 2.6 per cent. against 6 per cent.

CURVES.—Curves of 289 feet radius (19 degrees 50 minutes) connected by minimum tangents of 40 meters (131 feet), against 16 degrees 30 minutes to 17 degrees 40 minute-curves (325 to 350 feet radius) connected by no tangents at all for many successive reversions. The writer considers that the difficulty and expense of maintaining these

* *Railroad Gazette*, June 8th, 1883.

two limits is about equal, but that the latter is decidedly the most objectionable.

AMOUNT OF CURVATURE.—On Mexican Railway 143 curves on the last 20.14 kilometers of the ascent, against 82 curves on the upper 19 kilometers of the Jalapa line, shown on Plates LXXXIV and LXXXV. The lower portions of the line will be seen on Plate LXXXIV to have much more favorable alignment.

The number of curves indicates, what is the fact, that there is hardly any tangent on the upper portion of the Mexican Railway grade, whereas on the upper third of the line, shown on Plates LXXXIV and LXXXV, 41½ per cent. of the line is tangent (the average tangent being 96.3 meters or 320 feet), and on the whole 54 kilometers which have been engraved 48 per cent. of the line is tangent. The comparative degrees of curvature cannot be given.

DISTANCE.—The distance between Vera Cruz and San Marcos, where the two lines as actually surveyed connect, was just 20 kilometers (12½ miles) longer via the Jalapa Line, viz. 262 against 242 kilometers. Had the purpose in view been the same however, merely to get to Mexico, this difference might have been more than eliminated, as will be clear from the dotted line above San Marcos on Plate LXXXIII.

GAUGE.—The Jalapa line was intended to be laid to 3-feet gauge, corresponding to the gauge of the Mexican National Railway, whereas the Mexican Railway was 4 feet 8½ inches gauge. No difference was made in the location however on account of the gauge, the road-beds having been taken as 14 and 18 feet, slopes 1 to 1 in cuts and 1½ to 1 in fills, and rails estimated at 56 pounds. The ties were estimated at \$1 each, only 7 feet long, which was the only item estimated in any way lower because of the gauge.

COST.—In Table No. 1 is given an abstract of the large estimate blank prepared from the careful paper location of the entire mountain grade. Table No. 2 is an abstract closing a report by the topographer, giving in detail the material on the line, from which, in connection with Plate LXXXV, its very favorable character will be seen. From these and the maps and profiles submitted, which even in the reduced engravings show the estimated quantities at each point, any engineer can form his own judgment as to whether the estimate in Table No. 1 is adequate. The writer's belief was, and still is, that it is entirely adequate, and if so the cost of the entire mountain grade, with 30 per cent. added for en-

gineering and contingencies, amounts to less than \$40 000 per mile, against \$184 677 per mile for the actual cost of the mountain grade of the Mexican Railway, or in the ratio of 1 to 4½. A ratio of 3 to 1 is believed to be the very lowest which could be claimed to correctly represent the relative work. Unfortunately the writer was never able to obtain exact figures of the quantities on the Mexican Railway. Therefore he is reluctant to claim more than is certainly just.*

* The general route of both lines here described is shown on Plate LXXXIII. On Plate LXXXIV is given a reduction to one-fifth scale, or $\frac{1}{10}$ inches per mile, within 1 per cent.) of the large topographical map on a scale of $\frac{1}{10}$ of the upper 54 of the 117 kilometers of the mountain grade. This in turn was reduced from the original field sheets on the large scale of $\frac{1}{10}$ or 83½ feet per inch; which the difficult character of the work made necessary. The topography was very accurately taken by a skilled topographer, Mr. Max Chapman, M. Am. Inst. M. E.

On Plate LXXXV is given a photographic reduction of the original profile, which was called off, station, by station in the usual way from a paper location on the original field sheets, and estimated, station by station, from tables, with allowance for surface slope, which often more than doubled the level section quantities. The estimated quantities for each cut and fill are given on the profile and nature of material indicated. Retaining walls were estimated for at every point where a fill would not catch and are indicated by a thick line on the profile. The small amount of masonry is due to the almost entire absence of surface drainage and running water, as elsewhere noted.

The line, profile and estimate here shown were not finalities, but prepared for a special purpose. Compensation for curvature had not yet been introduced. It was fully expected to do still better at points, and in fact the location shown was greatly improved in the upper section (9) by a new line, run just before the suspension of work which threw the line back from the ragged cliff-work near the summit. As maps and profiles of this improvement cannot be given, no claim in respect to it is made, but only for what had been actually secured and recorded in black and white.

TABLE No. 1.

Abstract of the Detail Estimate of the Mountain Grade of the Jalapa Line, by sections subdivided according to the character of the work.

No. Section Length, Kilos.	Sections shown by accompanying map and profile beginning from summit.					Lower part of mountain grade.				Total of mountain grade.
	9	8	7	6	5	4	3	2	1	
Earth.....	19	15	20.5	24.4	14	17.1				110.0
Loose rock.....										
Solid rock.....										
Excess found.....										
Total excess.....										
Tunnel.....										
First-class masonry.....										
Culvert.....										
Retaining wall.....										
Paving.....										
Viaducts.....										
Bridges.....										
Total to sub-grade.....										
Per kilometer.....										

Price.

\$0 20

50

1 50

75

90 00

10 00

7 50

4 00

3 00

Estimate.

Earth.....

Loose rock.....

Solid rock.....

Excess found.....

Total excess.....

Tunnel.....

First-class masonry.....

Culvert.....

Retaining wall.....

Paving.....

Viaducts.....

Bridges.....

Total to sub-grade.....

Per kilometer.....

\$46 275

284 744

450

331 469

6 300

1 715

1 710

63 444

210

19 680

\$48 649

56 527

338

105 514

4 600

2 902

180

3 564

\$157 441

88 331

519

157 960

5 600

990

345

24 850

\$87 226

1 055

832

3 920

4 665

171

53 803

\$75 005

13 093

300

92 524

9 000

16 920

3 075

\$38 649

38 949

1 360

1 950

\$456 345

13 093

341 271

4 088

814 797

15 300

34 115

15 292

63 444

2 292

98 323

3 564

\$424 528

22 344

\$176 174

12 584

\$97 410

3 992

\$42 430

2 481

\$1 047 047

9 519

Average for 54.5 kilos.....	\$13 414	55.5 kilos. ave.	\$5 694	\$9 519
Track and ballast per kilo.....	6 773		6 773	6 773
Total per kilo.....	\$20 187		\$12 467	\$16 292
Total per mile.....	32 483		20 063	26 220

Total for mountain grade complete, 110 kilos. (68.35 miles.) \$1 792 100 = \$26 220 per mile.

Not including engineers, contingencies, shops, sidings, telegraph, etc., 10 per cent. was allowed for engineering, 20 per cent. for contingencies, and \$224 000 between Vera Cruz and Puebla for the other items, the whole increasing the above sums by about 35 per cent., or to an average of \$35 392 per mile, excluding rolling stock.

NOTES AS TO MATERIAL.—EARTH.—The material is invariably good, dry earth almost wholly free from stone.

LOOSE ROCK.—None occurs, except in Section 5. Much of the lava on the upper sections is really loose rock, but is classed as solid.

SOLID ROCK.—After passing below Section 8, the material is all earth except a small amount of loose rock. On Sections 8 and 9 the material classed as rock is mostly porous lava, which is largely loose in pieces of 1 cubic meter or less.

TUNNELS.—The upper tunnel (100 meters) is in hard white rock, the lower (70 meters) is in a soft chalk-like volcanic material. The price of \$90 per lineal meter is ample.

MASONRY.—The amount of masonry is very small, from the fact that no considerable drainage is encountered on the lower section, the line being chiefly a ridge line, and on the upper section the soil is so porous that no considerable water flows on the surface, as is shown by the culverts in the *camino real*, mostly just above the line. Good stone and lime exist on the spot in Sections 5, 8 and 9 where most of the masonry is. For the remainder the haul will in general not be long.

VIADUCTS.—Seven in all were required, aggregating 785 meters, the price being estimated for each separately. Only two short bridge-spans (9 meters—30 feet each) are required on the whole mountain grade, apart from the viaducts hardly any running water being crossed.

TRACKS.—The best material for ballast was readily accessible. Rails weighing 55 pounds per yard were allowed for, at \$60 per ton. Mezquite ties, 7 feet by 6 inches by 8 inches at \$1 each. Joints, \$1 25. Ballast, 1 610 cubic meters per mile, at \$1. Laying track, \$644 per mile.

TABLE No. 2.

Statement of Distances on the Line, and Kind of Rock and Other Material Passed Over.

[Prepared by Max Chapman, M. Am. Inst. M. E., Topographer of Mr. Elliott's party, accompanying a detailed report on the material encountered on the line, deposited with other original papers with the Society. The stations specified on the map are 100 meters long, as shown on the engraved profile, Plate LXXXV. Ten of them make a kilometer; 16— a mile. It will be seen that the amount of material estimated as rock is somewhat larger than this table indicates.]

FROM STATION	TO STATION	KIND OF MATERIAL ENCOUNTERED.
0	1	Heavy loam, clay and sand.
1	23	* { Argillaceous chistose sandstone (soft).
23	26	{ Argillaceous chistose sandstone.
26	56	Loam and clay.
56	70	† Massive conglomerate sandstone.
70	81	Loam and clay.
81	85	Lava (recent flow).
85	93	Loam.
93	115	{ Syenite and granite.
115	146	† { Syenite, granite, porphyry and basalt.
146	156	{ Limestone.
156	162	Lava.
162	183	Limestone.
183	209	‡ Limestone and basalt.
209	246	{ Lava (ancient flow).
246	300	§ Lava.
300	358	{ Lava (ancient flow).
358	372	Loam and clay.
372	377	Syenite in ridges (not exposed directly on line).
377	417	Loam, clay, sand and gravel.
417	420	Loam, clay, sand, gravel and sandstone.
420	520	Loam, clay, sand, gravel, basalt and sandstone.
520	582	Clay, gravel and basalt.

* Estimated to be overlaid with an average of 1 meter of soil.

† Estimated to be overlaid with an average of 2 meters of soil.

‡ Estimated to be overlaid with an average of 3 meters of soil.

§ On this long distance of 15 kilometers (as also more or less on the above sections), the rock was estimated according to circumstances. At points the lava was exposed; at others deeply covered with soil. In the hollows, or by going a short distance at almost any point, earth for making fills could be obtained. The line was therefore carried chiefly in fill.

SUMMARY.

	STATIONS.
Loam, clay, sand, gravel, etc.....	274
Basalt overlaid with 3 meters of earth.....	26
Basalt, lava, etc., overlaid with 2 meters of earth.....	77
Ancient lava overlaid with 1 meter of earth	149
Soft sandstone overlaid with 1 meter of earth.....	25
Exposed rock, lava.....	10
Limestone.....	21

Total (extending 32 stations below limits of engraved profile).. 582

Make what allowances one will, there is a great contrast in these two lines, and it therefore becomes of interest to consider how this latter line was obtained.

In March, 1881, the writer was engaged by the Mexican National Railway Company to act as engineer in charge of location and surveys on the various lines for which they had concessions, extending from the City of Mexico to the United States and to the Pacific Coast. On landing at Vera Cruz, with a large staff, under orders to report in Mexico, he was surprised at the receipt of a letter of instruction to the effect that a corps were engaged in examining a line from Vera Cruz to Mexico via Jalapa, and that he should detach another corps for service on this line, sending forward the remaining parties by rail; that he should then make a reconnaissance "sufficient to determine the general possibilities of the route, taking such escort as might seem necessary;" set the new and old parties at work; and not delay date of report in Mexico "more than six days."

To one landing in Mexico entirely ignorant of the language and the country; provided with no map or profile of the existing line, and knowing nothing more of its character than the general fact that it was one of the heaviest and most costly railways in the world; unaware that its engineers had even given a thought to a route via Jalapa, or even that there was such a place, until he finally learned that the route had been examined only to be abandoned, and that the branch which had been built to Jalapa, at the foot of the mountain proper, had 10 per cent. grades, and was practicable only by horse power; unaccustomed to a tropical climate and to the saddle; provided with no map of the region better or much larger than Plate LXXXIII which accompanies this paper; and innocent of all knowledge as to how large an escort would insure safety, if indeed any could—these were sufficiently formidable instructions, and could never have been successfully carried out, as fortunately they were to the letter (barring two days' delay from an unseasonable rain), had reconnoitering such lines been in fact so entirely lawless a matter that there was nothing for it but to look over the whole country and then decide what to do, or at least to try for.

The line which was found to be under examination is indicated by dotted lines on the general map herewith, and was at once rejected as impracticable and absurd. It ran from the coast northeasterly to Jalapa, 4500 feet; then descended southerly, 850 feet in about 10 miles, to an

elevation of about 3 650 feet at Coatepec; then was expected to ascend somehow, some 7 000 feet, to the "pass" between the volcanoes of Orizaba and Perote, at an unknown elevation, estimated at 10 700 feet, in an air-line distance of some 15 miles; and then to descend some 2 000 or 3 000 feet, on the back slope of the mountain, to the general level of the plateau. Very naturally the best grades which it was even hoped to obtain were those of the Mexican Railway, or 4 per cent. uncompensated.

It was at once clear that either something considerably better than this must be obtained, or the line should be reported as impracticable and the whole staff withdrawn. And it seemed equally clear to the writer that either a considerably better gradient than on the existing line must be obtained, and lighter work as well, or the project reported as undeserving of any consideration financially. A reasonable hope for a maximum grade of not over $2\frac{1}{2}$ per cent. at most was therefore fixed upon as the highest one justifying setting parties at work on it, and hence to be considered at all; and this, to make the project a meritorious one, required that 2 per cent. should be sought for. This made it indispensable to gain considerable development for the ascent, and this in turn made it out of the question to ascend between the two volcanoes, even had the saddle between them been cleft down to the level of the main plateau, which was known not to be the case. The whole problem therefore turned upon the question of whether or not it would be possible to turn northward at Jalapa (assuming that point to have been successfully reached by the required grade, which seemed a minor question) and run parallel with the coast line and the coast range, gradually ascending with all possible development, and turn the mountain of Perote to the north.

This possibility the writer was satisfied would turn, negatively at least, upon the simple question of whether or not there was some kind of an established highway ascending from Jalapa to the plateau, following in a general way the same course, and turning the mountain to the north. That is to say, the existence of an highway would not prove the line was practicable, but the absence of it would go far to prove that it was impracticable. In respect to highways, the writer had even then learned by sad experience, and had repeated occasions in the next three years to realize still more fully, that the route of an highway is ordinarily the worst possible guide for a locating engineer, except as

it may serve the negative purpose of a danger sign to warn him away. He now recalls no less than twenty-three instances on the lines in Mexico under his charge where the existence of a traveled road proved merely a snare to deceive. Some of these instances were of a very curious character and of much technical interest, but description must be forborne.

But in regions of real difficulty, where the elevations to be surmounted become serious even for animal power, and even after all avoidable rise and fall has been eliminated, the case is different. The writer's experience and conviction is that in such cases the aggregate intelligence of the cows and the natives thereabout may safely be trusted to discover and utilize the very best route there is for surmounting the elevation with the least amount of work. Even what would be regarded in Mexico or Colorado as so simple a problem as that of making the 900 feet rise over the Allegheny Mountains in Pennsylvania is a case in point. The pass above Altoona and Hollidaysburg was discovered and utilized in the very earliest days of the settlement of the country, and four generations of engineers on four successive public works have been able to do no better.

The first question asked by the writer, therefore, after learning the details of what was doing, was whether there was a traveled highway turning the mountain to the north, the map before him not extending far enough north to show that region distinctly at all. He was informed at once that there was, and a very old and good one. Had the response been otherwise, he should have regarded the result of the reconnaissance as practically decided then and there. The statement was coupled with another, however, that this route had been examined by the engineers of the Mexican Railway, and reported far less practicable than the line afterwards adopted and built, so that the middle line described was under examination as the only hope left.

This was discouraging enough; but on further learning that the highway had been for three centuries preceding the railway era the leading one between the interior and the coast; that there was no succeeding descent, but rather a gentle rise in it for many miles after the mountain grade proper was surmounted; that the summit was (this afterwards proved an error) several hundred feet lower than that of the Mexican Railway; and some other facts which seemed hopeful, there appeared to be a fighting chance, which was at least the only chance, that the line might be developed to give the requisite grade.

The more immediate question became then to make the ascent of 4500 feet to Jalapa, and it was at once apparent that to have any hope of doing this on such favorable grades as were alone worthy of consideration under the circumstances, the line must be carried down to as low an elevation as possible, parallel with the coast and the mountain slope, by running south from Jalapa toward Coatepec before beginning to lose distance by turning eastward to the sea. It appeared probable that the 850 feet of fall between these two points, as to which some definite knowledge was available, could not be made on a steeper grade than 2 per cent., and it was this fortunate fact (as it proved) which first led to conducting the reconnaissance from the beginning on the fighting chance of obtaining a 2 per cent. grade.

It was now determined, therefore, that the line, if there was to be any, must pass from Vera Cruz to Coatepec, and thence to Jalapa, instead of to Jalapa direct. Coatepec lies at the head of a river of considerable size, the Rio Antigua, which runs from it directly east to the coast; and the map and known elevation of the town made it at once clear that there was no physical impossibility in descending this valley directly on a 2½ per cent. grade, or perhaps less, if the valley had a tolerably uniform descent. It needed but the most moderate knowledge of the general laws of topography, however, to make it practically certain that no even approximately uniform descent could be hoped for in a river flowing in a deep gorge, cut through what was practically only a narrow footing to the most tremendous mountain slope on this continent. The foot-hills of a slope which reached a height of 17 873 feet and started practically from the level of the sea, was certain to have, like all such slopes, a decidedly concave profile.

Nothing less than 5 per cent. could be rationally hoped for in following the bed or immediate slopes of the valley, and it therefore became quite certain that the line descending from Coatepec must start from the lowest point at the head-waters of the Rio Antigua which it was possible to obtain, but speedily rise up on the higher slopes of the valley and out of the influence of the stream, until at last—and probably within a short distance—it would rise above all supporting ground. No resource would then remain but to turn across northwardly, at some favorable point on the dividing ridge, into the valley of the next river to the north, the Rio Chachalacas, with the view of gaining only such limited development as might be necessary to catch upon some high point on what

were known to be the gentle slopes of the lower valley of that river, from which the line could descend eastwardly on the required grade to sea-level at a point as near to the coast as possible. The only fear in this process, besides the danger of heavy work, was that it might be unavoidable to make a long horse-shoe development up the valley of the Chachalacas, bringing the foot of the grade far inland from the sea, and causing just so much unnecessary loss of distance on a level before reaching the foot of the mountain grade. The existence of these two parallel and deep lying streams made it certain that the general scheme below Coatepec would be practicable, if not too costly; and the immense depth of the southerly valley, which varied from 1 000 to 2 000 feet, together with the absence of all supporting ground to the south of it, made it certain that the line could at no point turn south between Coatepec and the coast.

Thus, by a process of exclusion, the entire line was projected and sketched upon the map, with most dismal apprehensions of the character of the work which would be encountered, but with absolute confidence, expressed at the time to the gentlemen who accompanied the writer on reconnaissance, in the face of some opposition, that if this line was not practicable, there was nothing in the region which was sufficiently defensible, from an economic point of view, to make it even worth examination. The line shown on the general map (Plate LXXXIII) which the writer now has the honor to lay before the Society, does not differ by its own width at any point in the entire ascent of nearly 8 000 feet to the plateau from that which the writer thus sketched upon the map in the City of Vera Cruz, and showed to several gentlemen, on the evening of the day when he first landed in Mexico; within two hours after first learning that there was such a place as Jalapa, or that there was, or ever had been, such a project as an ascent to the plateau through that region, and with the elevation of only two points on the line, Jalapa and Coatepec, approximately given. Neither does the line on Plate LXXXIII differ by much more than its own width at any point from the position of the line as finally surveyed, as shown on the detailed maps and profiles which are herewith laid before the Society complete, the more difficult upper half of the mountain grade only having been engraved on Plates LXXXIV and LXXXV.

The writer would not be understood to assert or imply that equal positiveness in defining in advance the limitations of reconnaissance is

often possible. On the contrary, he has never known another instance just like it, although it became his duty later to consider projects for several other lines of a similar but less exacting character. But the peculiar conditions, it will be seen, left no escape at any point from the chain of reasoning. Had there been no existing parallel line, one might have justifiably taken the region for better for worse, and borne with equanimity finding it a great deal worse than he took it for. As it was, the fighting chance for a low grade was the only one economically worthy of attention, and this primary fact given, the conditions left no escape at any point from the train of reasoning that it was that one route or nothing.

The next morning at daybreak the reconnaissance began, and was pushed through with increasing confidence as fast as the animals could stand it, or at the rate of some 40 miles per day, the entire examination of the mountain grade occupying three days—such haste being merely in fulfillment of the writer's positive instructions, and naturally against his inclination. Less time was required, however, because the only real purpose of the reconnaissance was not to find a route, but to examine on the ground the features of what was already known to be the only route affording a rational chance of success. The first 1 500 feet of rise was seen to be on slopes smooth in detail, but sufficiently steep for laying down a surface line on almost any grade, and were not examined critically. The dividing ridge was then followed up, to judge of what was really the only critical point of the lower descent (from the point of view of possibility and not of cost), the passage from one water-shed to the other. A long and sharp spur ridge running eastwardly from Coatepec about half way to the coast, having a crest 5 000 or 6 000 feet high, and standing at right angles to the main slope, was found to define the point where this passage must occur pretty definitely, and the material and topography was seen, with much relief, to be favorable for making this passage with as much or as little development as might be necessary, with considerable latitude in elevation and easy work. The south slope of this mountain, where the line would lie, was found to be almost impracticable for passage on horseback without camp equipage and time; but observing the north side to be fairly favorable, and taking it to be very unlikely that, in a ridge of this character, the topography would differ widely on the two slopes, it was passed by with a confidence that the result fully justified, as well as such very limited

information as was available at the time. It will be seen from the maps and profiles of this section (not engraved) that on the surveys now submitted, a few of the most costly single works on the line are here, and not on the engraved section above Jalapa, which was really the critical section. This, however, the writer is, and was then, satisfied was due chiefly to the fact that the lower section, not being a source of much anxiety, was left in less competent hands. In part it was radically improved almost at the conclusion of surveys, and the writer feels no doubt that it all might have been more or less, although he makes no claim in that respect. Owing to the falling away of the country to the south, before referred to, and the existence of the deep *barranca*, or gorge, in which the river lay, which cut down almost to sea level, or some 3 000 feet below the line, some of the most sublime views of the line were on this section; but its difficulty was not in proportion, in part because of the very fact that the line lay so high as to be above the immediate influence of the *barranca*. The material on all this section was exceedingly favorable.

The region between Coatepec and Jalapa was known to be not very rugged, and to oppose no difficulty as to elevation, so that it also was passed by with a confidence which the result justified, and the project was complete to Jalapa, as a basis for surveys, with a reasonably favorable 2 per cent. grade line all but assured.

For the critical section above, the distance by highway was found to be almost one-half too short, and all hung upon the possibilities of development. The material and topography on the lower half was found to be favorable for this purpose, being earth to a great depth, as noted, and sufficiently broken up by ridges and hills. A long stretch at about the middle of the slope, near the village of San Marcos, was of an equally favorable character, being literally an inclined plane on a slope of about 1 in 10—an old lava flow overlaid with soil—and not much broken up in detail. The upper section was rugged, but short, with considerable opportunities for rather expensive development.

The whole of this region was examined on the third day of a very heavy rain-storm, the end of which could no longer be waited for, and the examination was necessarily restricted to salient features only. On a long grade line of this character, however, the possibilities of developing on practicable ground to reach certain elevations at certain fractional portions of the available distance, can be judged of with some certainty, the general character of the slope being the main feature; and

the writer felt no real doubt then, or at any later time, that a grade in the neighborhood of 2 to 2½ per cent. was easily practicable, there being a certain considerable belt of favorable territory on which to place it, although above and below that the topography was much more forbidding. A leading factor in reaching this apparently hasty conclusion was the splendid and ancient highway already referred to, by far the best in Mexico, if not on this continent. It is a broad macadamized road with paved gutters, and a stone curb or masonry wall at the side, and the writer desires to pay a tribute of admiration and respect to the unknown engineer, whoever he was—very possibly one of the soldiers of Cortez, or one of his immediate successors—who laid it out. From a point near Jalapa to the summit, near Las Vegas, there is not a break in the steady ascent, and there are few points on it where a fresh team of horses would not readily break into a trot. The conclusion was natural, that if a Spanish soldier in 1530 could put something like a 6 per cent. highway down that mountain slope, an American engineer in 1881 ought to get a 2 per cent. railroad line down it, or take off his hat to his predecessor.

After reaching the summit, the continuation of the line to Mexico, or any other point on the plateau, was a detail offering no difficulties and needing no immediate study. The line was therefore reported on in writing to Mr. W. C. Wetherill, chief engineer, three days later (March 28th), as follows:

“The line under examination was too forbidding to be worth further attention. * * * I feel no doubt that the proper place for the line is to the north of Perote, and that something like a 2½ per cent. grade, or possibly a 2 per cent. grade, is practicable above Jalapa. Whatever grade is there obtained can certainly be continued down to sea-level and slope without excessive work. I have instructed surveys to be conducted above and below Jalapa on a 2 per cent. basis for the present, and consider the prospects for a fairly favorable line good.”

It should be mentioned further, that the writer's examination had been merely in a consulting capacity (the line not being formally a part of the Mexican national projects), and for some months later he had no permanent connection with or knowledge of the progress of the work, being absent on the Pacific slope. On being again asked to examine the line, August 1st, 1881, he found that his conclusions had been reported on as impracticable, and that a 3 per cent. compensated

grade had been adopted, located in part, and was under construction.* Fortunately however, a most intelligent assistant engineer, of great natural capacity for location, Mr. John S. Elliott, was in charge of the upper locating party. To his admirable conduct of surveys the success of this line was very largely due. Aided by information he had acquired, it was soon discovered that the abandonment of the 2 per cent. grade had been an over-hasty conclusion, from data which in fact assured its success. The work in progress was therefore stopped by the writer's advice; some \$30 000 of completed work abandoned, chiefly in the approaches to a costly tunnel in earth; and the writer appointed chief engineer, continuing in charge until some time after the completion of the surveys now laid before the Society, when the abandonment of all furtherance of the project by the Mexican National Railway compelled his resignation, and shortly afterward led to the stoppage of all work. But for the fact that he was favored with an unusually competent assistant in immediate charge of surveys on the more difficult section, the writer fears that he should never have been able to carry through the line with the limited time at his command.

Two features on the upper ascent are worthy of special note: One, the great lava flow shown on Plate LXXXIV, and before referred to, and the other, a still grander feature, the *barranca* of Zimilahuacan, a vast sink-hole in the earth some 2 or 3 miles in diameter, and some 3 000 feet deep by the barometer, about half of it sheer, with no transition or "ragged edge" whatever from the surrounding surface of the plateau, which was as smooth and treeless as an Illinois rolling prairie, but sloping about 1 in 12 or 15 in the chasm. This feature was encountered some miles beyond where all difficulties had ceased at the summit, and so smooth was the edge that the line skirted it with a mere surface line, so near to it that a stone thrown from the car window would fall sheer full 1 000 feet before touching. On the plateau the locality was so cold and so much exposed that it was stated that wheat would hardly head, while immediately beneath one's feet bananas, coffee, oranges and every form of tropical vegetation could be seen growing luxuriantly. A few miles beyond was a large and very ancient fortress still in good repair, but unoccupied, which would cost perhaps \$5 000 000 or \$6 000 000 to duplicate, in which for two centuries the great bulk of the silver pro-

* The concession permitted of no delay in beginning construction.

duct of Mexico was stored pending the arrival of transports at Vera Cruz. Several of the old line of visual telegraph towers which were used to communicate between the two points are still pointed out, although out of use more than a century. From several points on the upper ascent the City of Vera Cruz, 80 miles off in an air-line and 6 000 to 8 000 feet below, is visible in clear weather. These and other features make the region one of the highest interest to the tourist.

A line of almost equal engineering interest was located by the writer from the Pacific Coast at San Blas to the plateau, which he regrets that he cannot extend this paper further to describe. In Plate LXXXVI is shown its most interesting single feature, a bridge spiral, some of the details of which are shown in the notes accompanying the plate, and which was believed at the time to be the only bridge spiral in the world. Another one, however, on a smaller scale, had even then been located on the Georgetown, Breckenridge and Denver Railway, and has since been completed. It is as yet the only one completed, the construction of the Pacific Branch located by the writer having been suspended for lack of funds.

In view of what has preceded, the writer hopes that he may not be suspected of over-estimating the difficulties of securing such lines, or of personal inability to cope with them, when he declares his conviction that this whole method of taking railway lines up difficult ascents by a continuous succession of curves and tangents on a rising grade, over which the locomotive keeps up a steady march, is fundamentally wrong and bad, and one which might profitably be modified in nearly all cases when an elevation of over 1 000 feet, or possibly much less, is to be surmounted. To furnish a suitable background for the expression of these conclusions, by showing that they are formed in spite of fairly successful experience in following up the more usually approved plan, is a main purpose of this paper.

Three general methods for surmounting such elevations, besides the almost universal one, are more or less in use:

First.—Rack or grip railways.

Second.—Inclined planes operated by stationary engines.

Third.—Switch-backs.

The first of these was proposed in a practicable form over thirty years ago, and the two latter ante-date the locomotive itself. Either one of them is probably deserving of more use than is given it, but the third

(switch-back) the writer deems worthy of adoption by engineers as the standard plan for surmounting considerable elevations, always provided the switch-backs be constructed and operated in quite a different manner from that usual in the few which exist, which have for the most part only been resorted to as a last resource.

One feels a natural hesitation in expressing a conclusion which, it must be admitted at once, all the tendency of modern practice tends to discredit. The accumulated verdict of experience is rarely wrong, and it is undeniable that all these plans have been in many cases tried and abandoned, and have met decreasing favor. Nevertheless, causes needless to go into, other than lack of real merit, may explain in part at least this result, and the writer sees no escape from believing that they do so wholly.

The various forms of rack or grip railways have never yet won marked success for other than scenic lines of light traffic, where economy of operation was no great object. The most promising effort in this direction, by far, is the Abt system, recently described by Mr. W. W. Evans, M. Am. Soc. C. E., in a paper before this Society, which certainly has features of striking merit which will lead engineers to watch its progress with great interest. Among these are the rack with stepped or staggered teeth; the compound gear-wheel engaging therewith, with its peculiar elastic adjustability, insuring even bearing of the cogs on the rack at all times, and, above all, the admirably ingenious footing to the rack, by which a locomotive working by ordinary traction may approach the foot of the rack grade at ordinary working speed, retaining all its momentum, and leaving the adhesive traction cylinders still working, with certainty that the rack gear will engage smoothly and without shock, and work conjointly with adhesive traction thereafter, thus removing the most serious theoretical objection to the locomotive, that it is unable, except within a very limited range, to increase the tractive force exerted by it at the expense of speed. But with all these merits the apparatus is rather costly, both for maintenance and renewal, and its range for profitable employment must be limited.

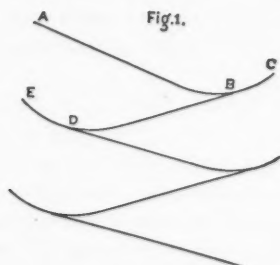
The capabilities of the inclined plane or cable plan have been greatly extended in recent years, as applied to street and local passenger service, and it is clearly destined in the near future to still wider use. Superficially, the record of its use in connection with ordinary railways is most discouraging to any hope of its future usefulness in that direction.

In the early days of railways it was constantly considered, and often used. A complete plant of the kind existed over the Allegheny summit of the Pennsylvania Railroad before that line was built, and was abandoned in favor of locomotive traction, even to connect two lines of canals. Several complete railways operated by successive inclined planes and gravity inclines were built in Pennsylvania and elsewhere—two in Northern Pennsylvania of considerable length, one of which is still in use and the other only recently abandoned, but not chiefly, if at all, for reasons affecting its abstract merit. It is not generally known that the existing main line of the Pennsylvania Railroad over the Alleghenies, which was built long after the old planes had been abandoned, was laid out with the distinct view of afterwards adding a new and enlarged system of planes for freight traffic when the volume of traffic had increased to justify it. This policy was favored by its distinguished chief engineer, Mr. J. Edgar Thompson, and some elaborate and interesting data in respect to it are given in the early reports of that road, notably in a report by the then Superintendent, Gen. Herman Haupt, in which the ground is distinctly taken that it is a mere question of volume of traffic whether inclined planes are economical or not.

That view the writer apprehends to be the true one. The fixed tractive plant is costly to construct, maintain and operate, and expenses are not greatly affected by whether the tonnage moved by it be large or small. It by no means follows that, because the system was wisely abandoned in favor of locomotive power, for the thin traffic of those early days, that it is wise to continue to neglect it at points where almost a steady stream of laden cars is to be carried, first up and then down a dividing ridge, day and night, the year round, as on the Pennsylvania summit, and at many similar localities. At such points it is demonstrable that not only may the great amount of power used in lifting locomotives be saved, but that the descending and ascending cars may be balanced against each other, thus largely eliminating the effect of the rise; while the superior economy of stationary engines will largely reduce the cost per horse-power, after allowing for the friction of cables, which, on a short, steep incline is a minor element. Especially now that the making of long continuous cables is so well understood, so that as long an incline as the topography permits may be readily worked, it is worthy of the most serious study whether a very large economy is not

readily possible at such special localities, a considerable number of which may be counted up.

A proper switch-back system, however, seems to the writer the most generally useful and meritorious for lines of probably thin traffic, as well as the most unquestionably practicable for use in all such localities. The germ of the proper system was contained in the first switch-back laid out in America, if not in the world—that at Mauch Chunk—which was used for dropping empty coal-cars down into the Nesquehoning Valley, before the tunnel of that name was completed. That track was used only for cars passing in one direction (descending), and was operated as follows:



The cars were started from *A*, Fig. 1, on a down grade of about 1 per cent., calculated to give a considerable velocity. At *B* an automatic switch, whose exact mechanism the writer cannot give, was run through and the car brought to a rest by the next succeeding up grade at *C*, from which it immediately started back towards *D*, passing through the switches *B* and *D* until again stopped at *E*; and so on indefinitely, the cars descending several hundred feet in all without the slightest attention, very rapidly, with very rare accidents, and with no one on them or stationed along the track.

Thus, to say the least, every advantage was gained that could have been gained by a long continuous descent, with the immense advantage that, owing to the entire liberty of choice as to the length given to each plane, the best alignment and lightest work available on any part of the surrounding country may be chosen.

But more than this was gained. Any long continuous grade which is steep enough to move cars with journals in rather bad order, must be steep enough to speedily give cars in good order a dangerous velocity.

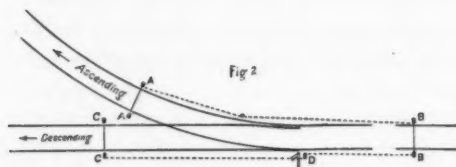
Thus, it would be impossible to let cars run of themselves down a continuous grade of any kind, while, on the switch-back, not only was this very readily done, but a pretty high average velocity could be safely used, from the fact that it in any case could not exceed a certain maximum. Again, when necessity required, it was easy to stop cars at any point.

Analogous advantages are readily obtainable, *mutatis mutandis*, by switch-backs operated by regular trains running in both directions, but not under the conditions of ordinary practice, which necessitates the complete loss of all the *vis viva* of the train at every switch. The plan shown in Figs. 2 and 3 will apparently obviate this necessity completely, and introduce no new elements liable to cause difficulty, but, on the contrary, give smooth, easy and rapid motion. The details of this plan are as follows.

AS RESPECTS THE SWITCHES.—The switches should be, and are easily made, entirely automatic. Their normal position should be that in Fig. 2, in position for running up hill, and not down hill. A runaway train or car cannot then pass a switch and continue down grade. As respects a train going up grade, this arrangement presents no difficulty. It may simply run through the switch *D*, springing the points over to let the wheels pass. Simple devices of many different forms may be used to restrain too rapid return of the points after the passage of each single wheel, but this is not essential, as the wear and tear would be small.

A train descending should be able to operate the switch, so as to continue descent, by a single act of the engineer, but only by intention on his part. This may be accomplished by a very simple and inexpensive apparatus, such as that outlined in Fig. 2, operated by a lever or idler wheel on the locomotive controlled by the engine-man, and with mechanism somewhat similar to that of the simpler forms of interlocking apparatus, which it would be superfluous to describe in detail, as it can be designed in a few hours by any signal engineer. The general method of operation is described below Fig. 2, the whole insuring that (1) up trains shall always pass the switches freely and automatically; (2), that runaway down trains shall never pass them, but be caught; (3), that regular down trains shall be enabled to pass the switches automatically by a single act of the engineer; (4), that careless neglect of this act shall do no other harm than to cause the train to run back again on the up track; (5), that danger signals shall be set when

the switches are wrong, or any part of the apparatus broken; (6), that the switches can at all times be operated by hand if desired, or if the mechanism is out of order.



MECHANISM FOR AUTOMATICALLY OPERATING THE SWITCHES OF SWITCH-BACKS.

The mechanism here outlined acts as follows :

DOWN TRAINS.—*A* places *B* and *C* in position to act, which are otherwise entirely inoperative.

B, when first made operative by *A*, opens the switch *D* for track *C*, and holds it open.

C, always operative when *B* is, returns *A*, *B* and *D* to their original positions. *A*, *B* and *C* are supposed to be located with reference to having the engine always at the same end of the train. If the engine be at the other end the switches must be operated by hand.

UP TRAINS.—If, by carelessness, the engineer of an up train should leave the switch-actuating lever down, nothing will happen except to set *A* as if for a down train, in leaving the switch-back. This will not effect following trains either down or up. Should a succeeding up train be equally careless it will act first on *C* and then on *A*, thus running through the switch with no effect.

AS RESPECTS THE ADJUSTMENT OF THE GRADES.—Fig. 3 shows in detail what the writer regards as the proper adjustment of grades for a 2 per cent. switch-back, and the principle of the adjustment for any grade. With this arrangement it is unnecessary for an up train to use brakes, or even shut off steam at all, for making the stop and then starting backwards.

It will be seen that the up grade continues unbroken until it has passed the switch and then rises in a sharp vertical curve, which rises above the regular grade, slowly at first, and at the further end—merely as a precaution against accidents—rises very rapidly indeed. This is to bring the train to a stop slowly and gradually, but certainly, without either shutting off steam or using brakes. The rise necessary to do this for any given train speed may be computed exactly, and is given in the following Table No. 3 computed by the writer and not elsewhere readily accessible.*

Suppose a train to be ascending the 2 per cent. grade at a uniform speed of 15 miles per hour. Then, by the table, a lift of 7.99 feet above the regular grade will bring it to a stop even with the engine still using steam. If the velocity be only 10 miles per hour, a lift of 3.55 feet only will be necessary, and this will or can readily be made to be the usual speed of approach. In that case, if the train consist of 10 cars and be 400 feet long, it will come to rest with the steam still on, unchanged, when the rear of the train has passed a little over 100 feet past the switch, the center of gravity of the train being then 3.55 feet above the tangent grade line. The slack of the train will be taken out, under these conditions, very gradually indeed, and almost at the instant of coming to rest.

If, then, without changing the throttle, the reverse lever be thrown over into back gear, or even merely into mid-gear, so as to do no work at all, the train will immediately start backward, still holding all the slack out of the train, which will continue out until forward motion is resumed at the next switch-back. If the lever were immediately placed in the same notch of back gear in which it formerly stood in forward gear (which would be unnecessary) the speed which the train would have acquired on resuming the upper straight grade at *T*, Fig. 3, would be that due to the height *c*, which is $3.55 + (8 \times 4) = 35.55$ feet; or, as per Table No. 3, $31\frac{1}{2}$ miles per hour, an objectionably high, but not dangerous, speed. Had the velocity of approach from below been 15 miles, this speed would have been that due to 37.99 feet, or only $32\frac{1}{2}$ miles per hour, and had the velocity of approach (in case of passenger trains) been even 20 or 25 miles, this speed would have been only 36 or

* The table is taken from the forthcoming revised edition of the author's treatise on "The Economic Theory of the Location of Railways," and has likewise appeared in the *Railroad Gazette*, March 26th, 1886, "Experiments on Train Resistance."

Fig. 3.

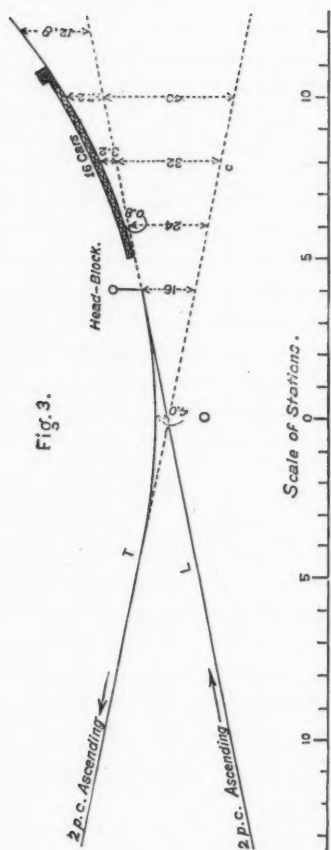


TABLE No. 3.

Giving the Total Energy of Potential Lift in Vertical Feet in Trains Moving at Various Velocities.—Including the Effect of the Rotative Energy of the Wheels for Passenger or Loaded Freight Trains, assumed at 6.14 per cent. of the total energy. For trains of empty flat or coal cars add about 4 per cent. to the quantities below, and proportionately for mixed trains.

MILES PER HOUR.	0.	Diff.	1.	Diff.	2.	Diff.	3.	Diff.	4.	Diff.	5.	Diff.	6.	Diff.	7.	Diff.	8.	Diff.	9.	Diff.	0
0	0.00	.04	0.04	.10	0.14	.18	0.32	.25	0.57	.32	0.89	.57	1.28	.46	1.74	.53	2.27	.61	2.88	.67	0
10	3.55	.75	4.30	.81	5.11	.89	6.00	.96	6.96	1.03	7.99	1.10	9.09	1.17	10.26	1.25	11.50	1.32	12.82	1.38	10
20	14.20	1.47	15.67	1.52	17.19	1.60	18.79	1.67	20.46	1.74	22.20	1.80	24.00	1.88	25.88	1.95	27.83	2.03	29.86	2.09	20
30	31.95	2.17	34.12	2.23	36.35	2.31	38.65	2.38	41.04	2.45	43.49	2.52	46.01	2.59	48.60	2.66	51.26	2.74	54.00	2.80	30
40	56.80	2.88	59.68	2.94	62.62	3.02	65.94	3.09	68.78	3.16	71.89	3.23	75.19	3.30	78.42	3.37	81.79	3.45	85.24	3.51	40
50	88.75	3.59	92.34	3.65	95.99	3.73	99.72	3.80	103.52	3.87	107.39	3.94	111.33	4.01	115.34	4.08	119.42	4.16	123.58	4.22	50
60	127.80	4.30	132.10	4.36	136.46	4.44	140.89	4.51	145.41	4.58	149.99	4.65	154.64	4.72	159.36	4.79	164.16	4.87	169.02	4.93	60
70	173.90	5.01	178.96	5.07	184.03	5.15	189.18	5.22	194.40	5.29	199.69	5.36	205.06	5.43	210.46	5.50	215.98	5.58	221.56	5.64	70

Formula: Vel. head = $\frac{v^2 \text{ in ft. per sec.}}{64.32} = \frac{1.467 v^2 \text{ (in miles per hour)}}{64.32} = 0.023445 v^2$

To which add 6.14 per cent. for rotative energy of the wheels = $0.002055 v^2$

Giving as the final formula, by which the table is computed, Vel. head = $0.025500 v^2$

39 miles per hour. Thus the switch, with grades arranged as shown, can be run through at any speed, making no more change in the brakes, steam or engine, than to throw over the reverse lever, at the moment the train comes to a stop, from full gear forward to full gear back.

With ordinarily careful and safe working, the speed at *T*, Fig. 3, would be about ten miles per hour higher than the speed of approach, a gain far more than sufficient to obviate all loss of time from the stop, and equivalent (for speeds of 10 miles per hour approaching and 10 miles leaving) to a subtraction of 10.65 vertical feet from the rise in the next grade—a gain which will considerably increase the average speed or hauling capacity, or both.*

Fig. 3 equally well represents the conditions at the next ensuing switch-back, where the train approaches rear-end to it, if we simply assume the engine to be at the other end of the train. It reaches the position shown, backing up from below, with all slack out of the train. In starting forward on the up grade, the rear end of the train, being on a steeper grade than the engine, will tend to crowd slightly upon it, and by setting the reverse lever in the second or third notch of forward gear, the slack will be taken out in the gentlest possible way, far more gently than is ever possible in starting on a level.

Thus the ordinary and great objections to sharp hollows in grade lines do not apply in this case. Or the contrary, the action is smoother than it would be without the curved profile. Similarly, the still greater objections to a stop on the grade line do not apply at all in this case. We rather gain by it, because the whole train stops and starts again with the gentleness and economy of energy of a pendulum, for identical mechanical reasons.

This being so—there being no loss of time, no loss of distance, no loss of hauling capacity, and no measurable loss in smoothness of motion—we have left as a net gain two things: *First*—A great additional safeguard

*If the train were running up a straight grade *L O T* at 15 miles per hour (say 22 feet per second) in $\frac{400}{22} = 18.2$ seconds.

Via the switch-back it takes:

$$\begin{array}{lcl} O \text{ to stop, 800 feet at average speed of about } \frac{0 + 22}{3} & = & 48.5 \text{ seconds.} \\ \text{Stop to } T, 1200 \text{ " " " " } \frac{0 + 37}{3} & = & 43.3 \text{ " "} \\ & & \underline{91.8} \end{array}$$

Loss of time, as nearly as may be, $1\frac{1}{2}$ minutes.

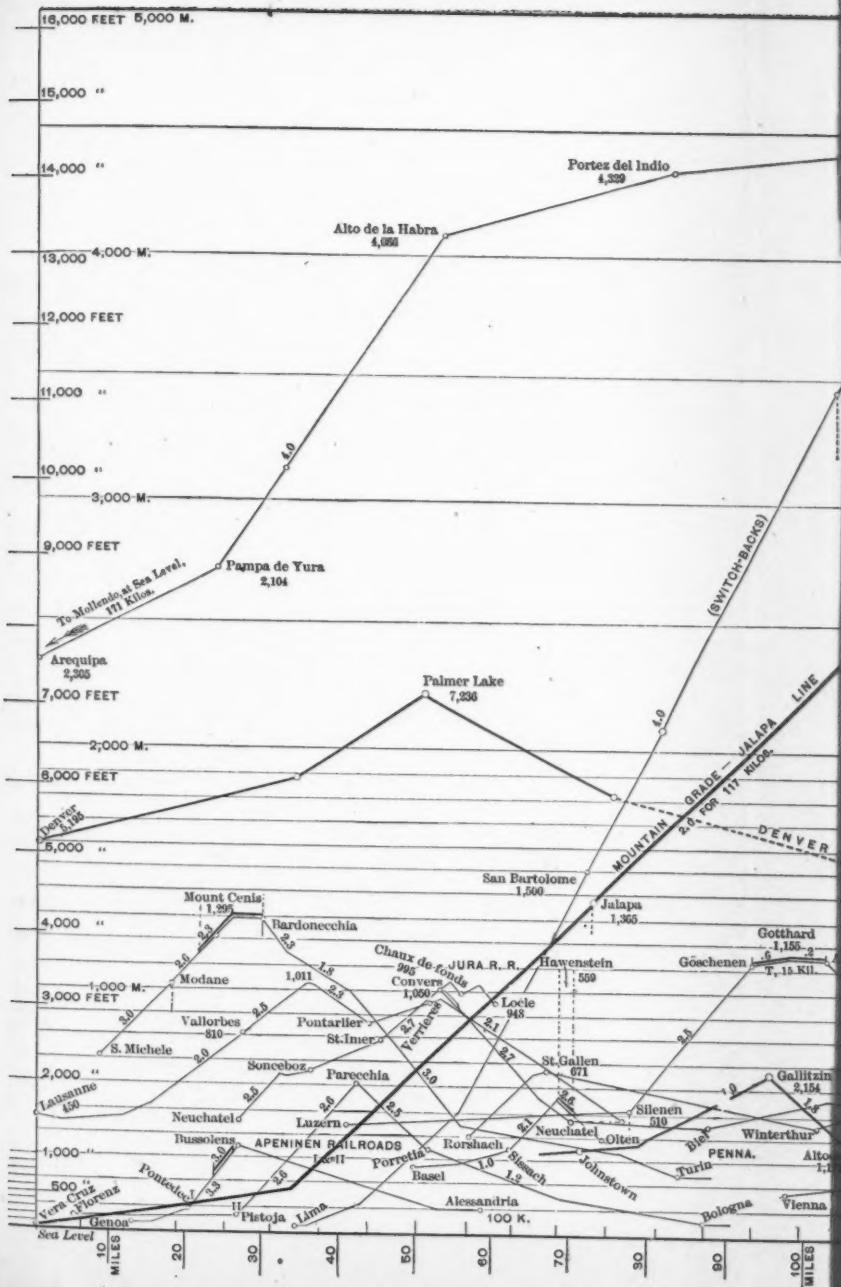
The train is then moving 10 miles per hour faster, so that it will save this lost time almost within the next mile.

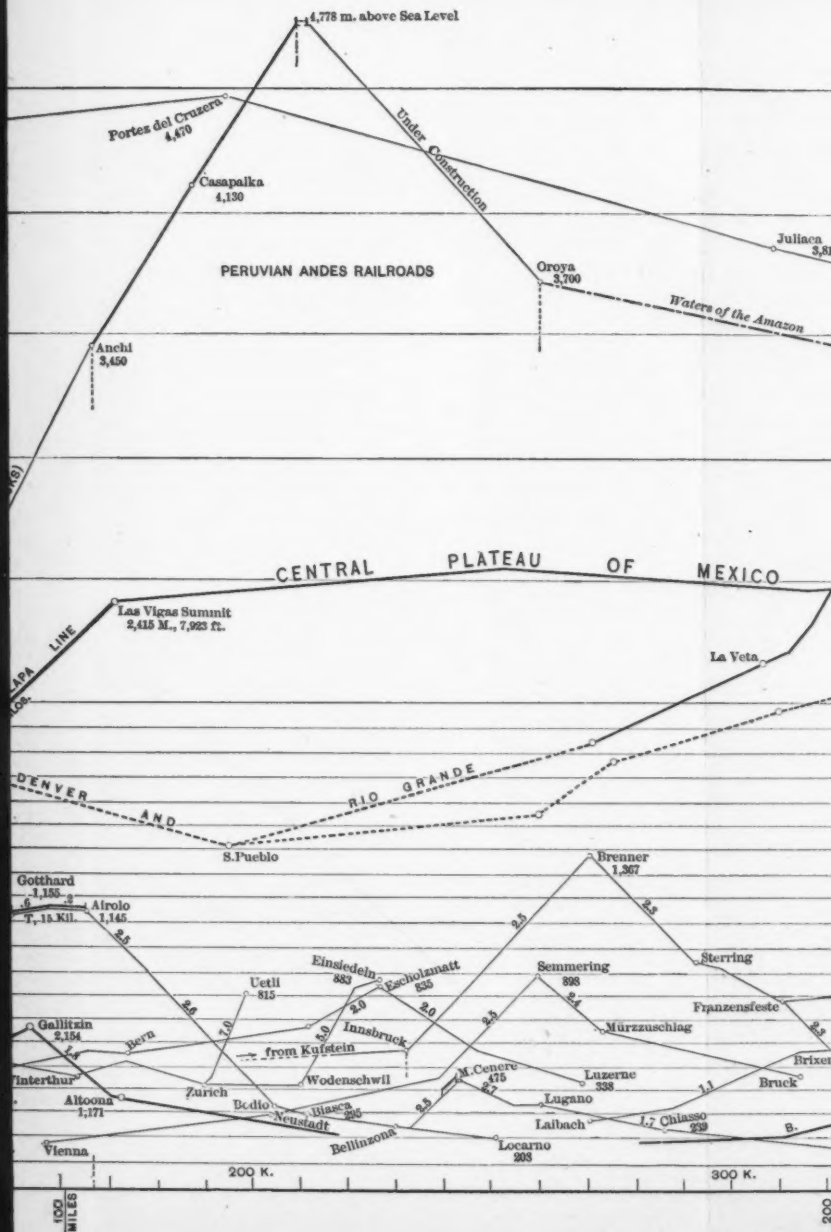
against collisions with and derailments of runaway trains or parts of trains. Accidents resembling the terrible one on the Southern Pacific, on the Tehachapi grade, some years ago, in which nearly all of a train-load of people were killed or injured, are not likely to occur. Before a train can attain a velocity of 60 or 70 miles per hour it must fall 128 or 174 feet in excess of the fall required to overcome its resistance. If we estimate its average resistance in acquiring that speed at 20 pounds per ton, equivalent to the acceleration on a 1 per cent. grade, a train must descend a 2 per cent. grade for $2\frac{1}{2}$ to $3\frac{1}{2}$ miles before it will acquire those velocities. A single car would take much longer yet, so that a switch-back every 3 or 4 miles would go far to insure against the worst results from such catastrophes, which no care can wholly avoid.

Second—A great reduction in cost of construction and amount of curvature, and usually in rate of gradient as well, is assured; in some cases more than others, but always considerable. In the line described in this paper, the writer estimates that half the curvature, and nearly half the cost of construction to sub-grade, might have been saved by using not more than eight or ten switch-backs on the whole ascent of 8 000 feet, through the better choice of ground afforded. An entirely different route would have been selected, and nearly the whole line might have been reduced to but little more than a surface line.

On the other hand, there is the unquestionable disadvantage in switch-backs, that engines do not pass curves well running backward. In part this is remediable in the design of engines, and by leaving the rear drivers blind, but the only proper course would be to use an easier maximum curve on the sections on which the engine runs backward, which would be the same both ascending and descending, and to make those sections as short as possible.

Thus, the writer believes, this objection, while it cannot be entirely removed, may be reduced to very small dimensions; and should it again fall to his lot to locate a line of railway upon an ascent of 8 000 vertical feet, or even a half or a quarter—or, possibly, even an eighth—of that amount, he will in no case willingly attempt to locate it for an unbroken locomotive run, but either use switch-backs for a light traffic, or study with great care the possibilities of the locality for inclined planes with a heavy traffic.





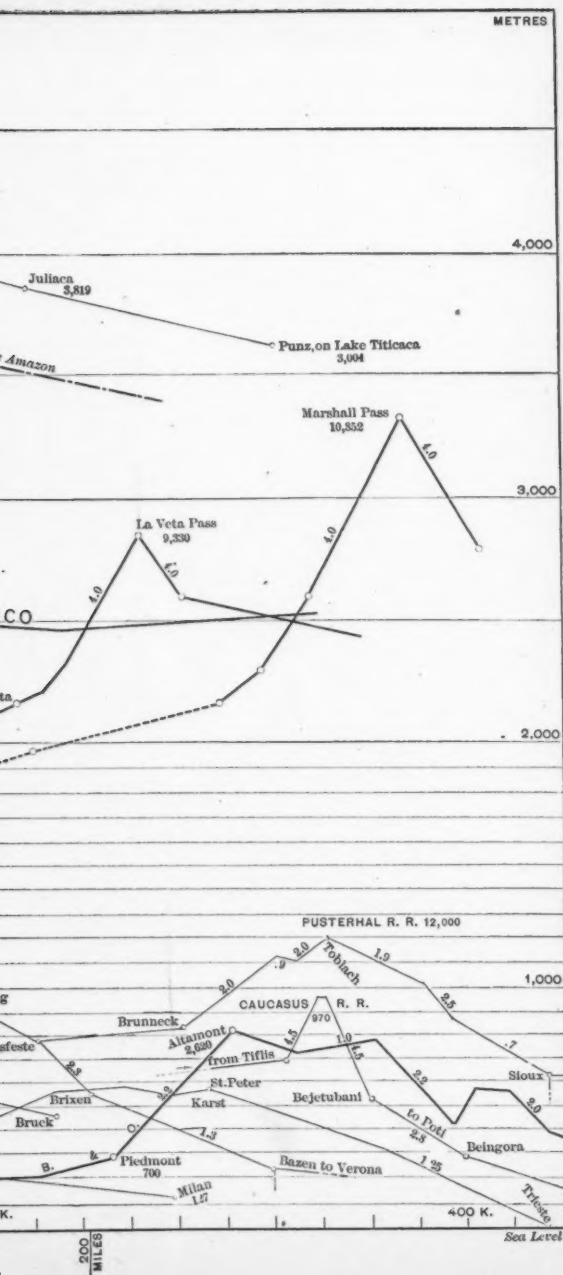
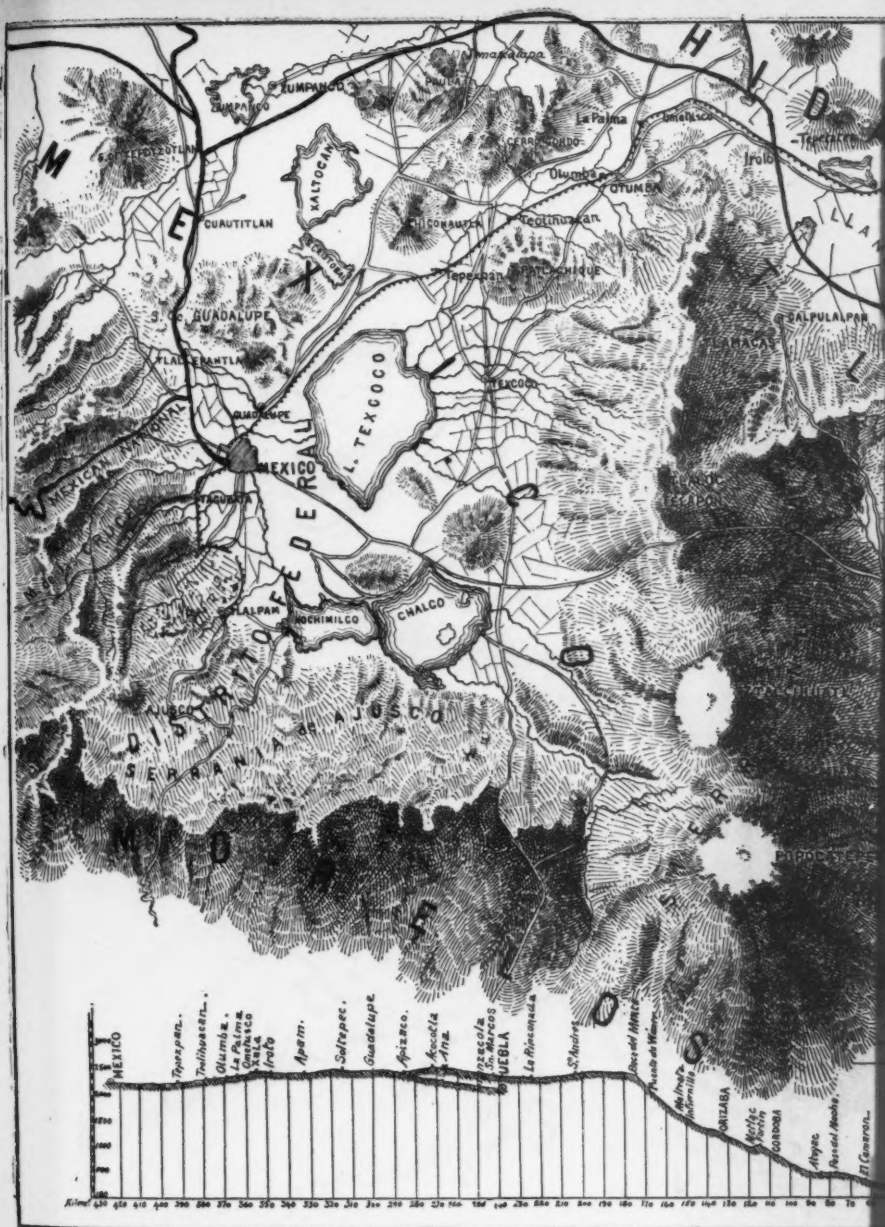


PLATE LXXXII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XV, No. 344.
WELLINGTON ON
RAILWAY LINE IN MEXICO.

NOTE TO PLATE LXXXII.

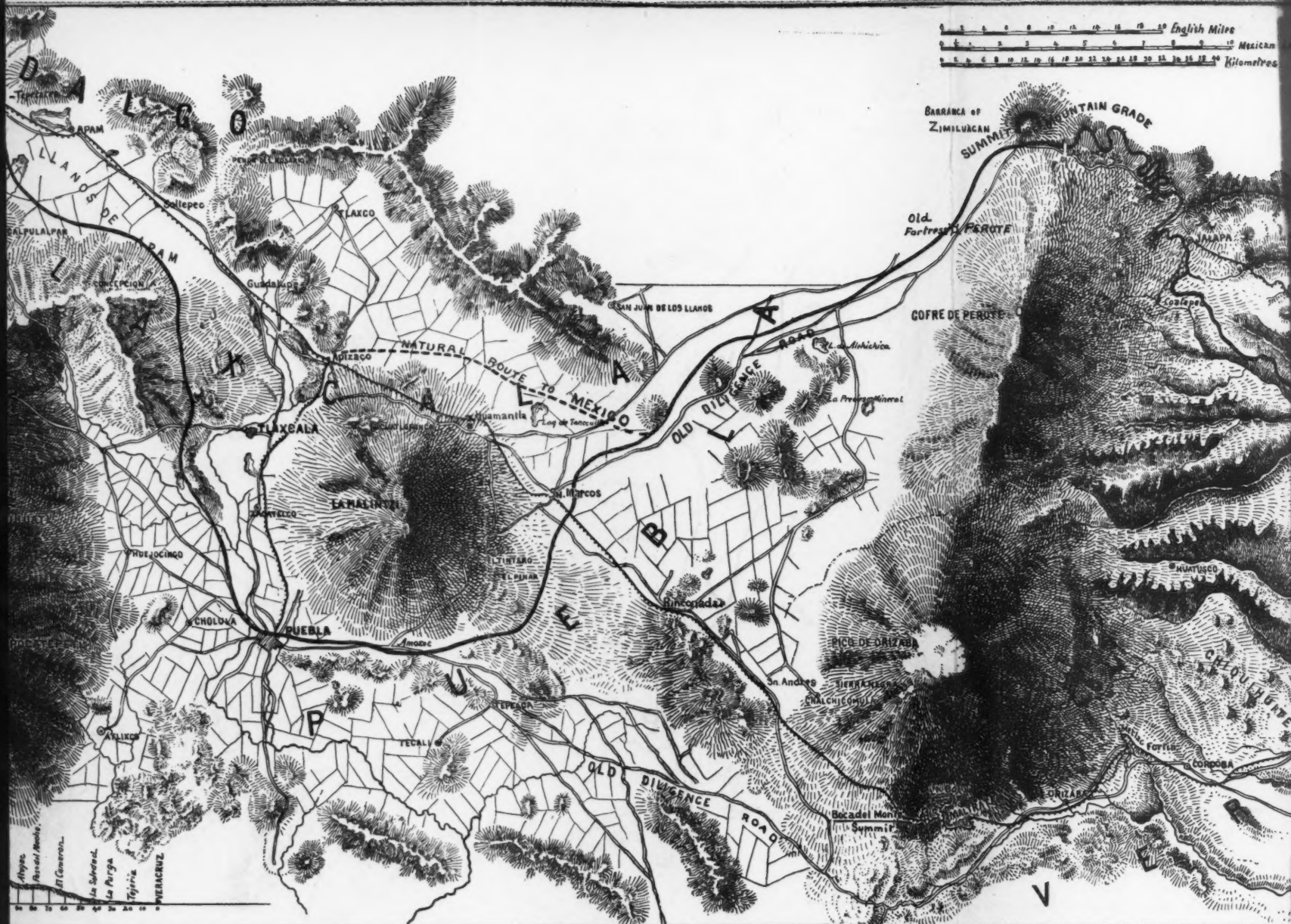
Only the lines shown in comparatively heavy lines on this plate, viz.: The Jalapa line from Vera Cruz, the Denver and Rio Grande, the Pennsylvania, and the Baltimore and Ohio are of the writer's compiling. The remainder has been reproduced from a plate prepared by Mr. W. W. Evans, M. Am. Soc. C. E., to show the Peruvian lines, and he in turn was indebted to European authorities for the admirable presentation of European railways. Comparative distances are of course to be estimated by the horizontal distance, since the exaggerated vertical scale exaggerates the slant length greatly.

A small profile of the Mexican Railway is shown on Plate LXXXIII. It could not conveniently be added to this plate for comparison with the Jalapa line. Its general nature will be indicated by projecting a 4 per cent. grade (parallel with the Peruvian line) from Las Vigas summit to the level of Jalapa, and then continuing down to sea level with mixed $1\frac{1}{2}$ to 4 per cent. grades, with some lost elevation.



This map is reproduced from one engraved to accompany the history of the Mexican Railway. The representation of the topography to the east of Orizaba and Perote is not particularly satisfactory.

The route shown for the Jalapa line after reaching the summit was selected (1) to reach Puebla, the second city of Mexico; (2) and chiefly



NOTES TO PLATE LXXXIII.

by the
graphy
it was
chiefly

to run through the heart of the *pulque* district between Puebla and Mexico; (3) to connect with the Mexican National system at a favorable point; and (4) with the idea that a line might be run southwardly from Puebla at some future day. *Pulque* is the national drink of Mexico, the fermented juice of the *agave* or Mexican aloe (century plant), and is

exported from the district in immense quantities by special trains.

A part of the route indicated, on each side of Puebla, has been constructed. Had the purpose been merely to reach Mexico in the most direct way, as with the Mexican Railway, the dotted line marked "Natural Route to Mexico" would have been followed; or possibly one

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PLATE LXXXIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XV, No. 344.
WELLINGTON ON
RAILWAY LINE IN MEXICO.

MAP OF REGION BETWEEN VERA CRUZ AND THE CITY
OF MEXICO, SHOWING THE LINE OF THE MEXICAN RAIL-
WAY AND THE JALAPA LINE AS ORIGINALLY SKETCHED, AND
IN SUBSTANCE AFTERWARDS, LOCATED BELOW PEROTE.



still further to the north, making the Jalapa line from 20 to 50 kilometers the shortest to Mexico. It was beyond question an error of judgment that the main line of the Mexican Railway was not carried through Puebla, as might have been done with perfect ease with equally favorable grades and moderate sacrifice of distance, with less total line to construct.

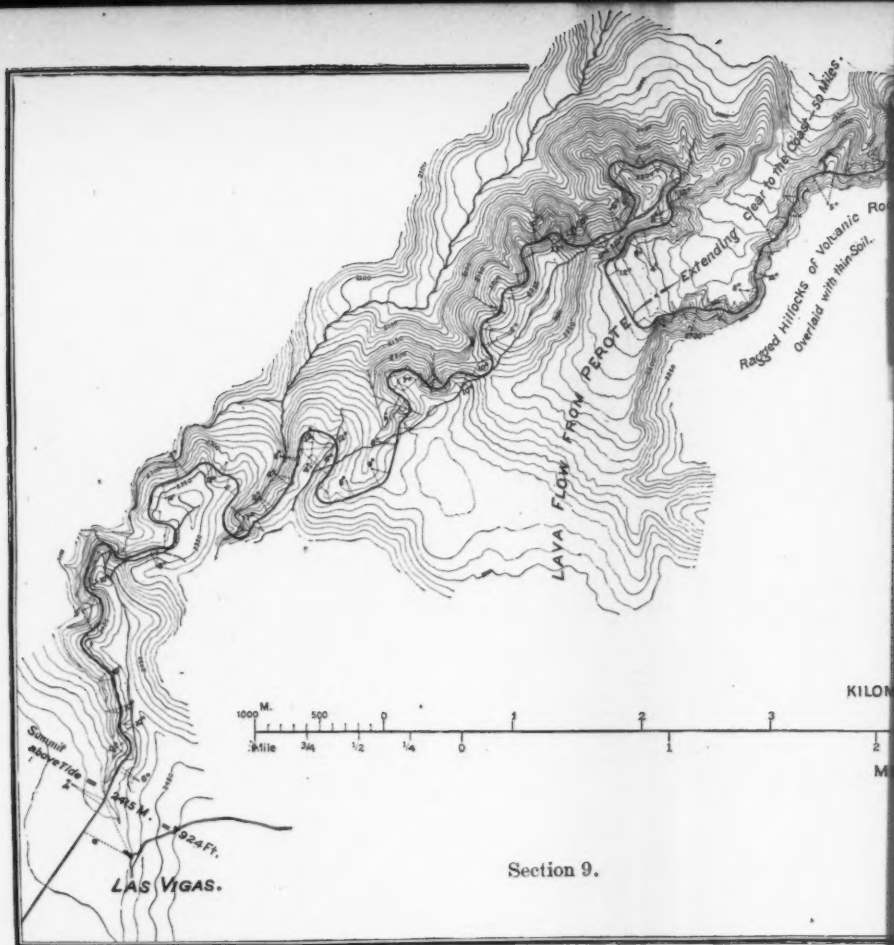


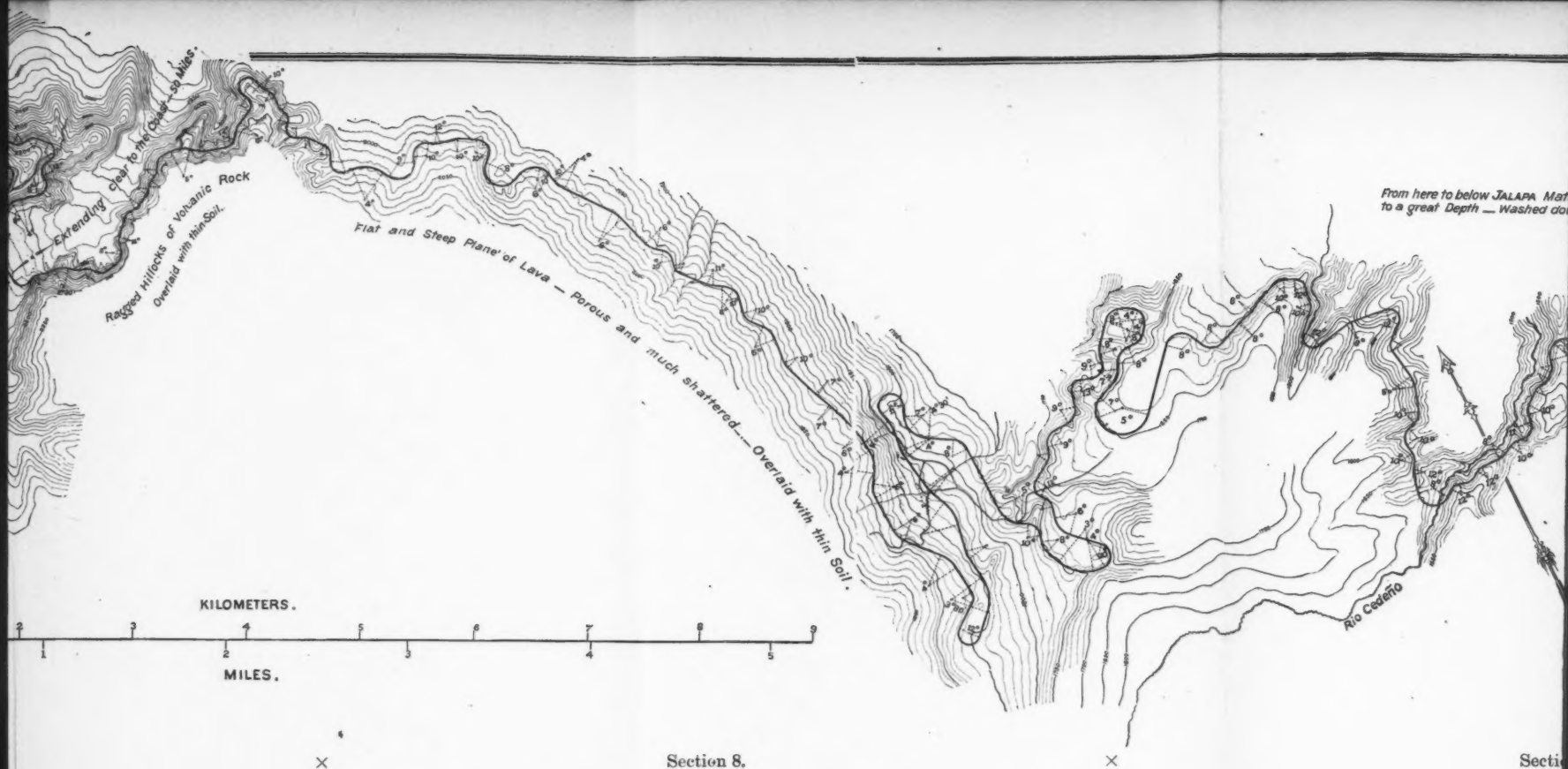
PLATE LXXXIV.
TRANS. AM. SOC. CIV. ENG'RS.
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WELLINGTON ON
RAILWAY LINE IN MEXICO.

The scale shown ($\frac{1}{100000}$) below the title is for the original map from which this was reduced. This reduction was intended to be on a scale of $\frac{1}{50000}$, but by error of engraver is a little less.

The degrees of curve given are for 20-meter chain (chord of 65.6 feet), and are somewhat more than two-thirds of the degree of the curves by the foot system (100-foot chords).

It will be seen by the border that the reduction of the two halves of this plate is not precisely correct. Owing to the size of the original map, it was impossible to photograph the whole plate at once.

Owing to the necessity of carrying off the original of this map to



NOTES TO PLATE LXXXIV.

the original map from
ended to be on a scale
r chain (chord of 65.6
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the size of the original
plate at once.
original of this map to

the United States before it was entirely finished, sketched topography
extending beyond the limits of could survey be added only at a few
points, and the kilometer marks could not be put on. As they could
not be added accurately to the map for engraving without access to the
original field-sheets, it was thought best not to add them at all. The
limits of the three sections (7, 8 and 9), into which the portion of the
line engraved was divided for estimating purposes, may be determined
by the following scaled distances, which likewise indicate the amount
of distance gained by development. Starting from the point near the
left-hand corner marked "Summit," we have in succession:

SECTION.	LOCATION.	LENGTH.		Increase by Develop- ment.
		By Air Line from Beginning to End of Section.	By Located Line.	
9	Summit to end of ragged cliff work*.....	8.5 kilos.	19.0 kilos.	100 to 224
8	End section 9 to middle of third horse-shoe curve.....	7.5 "	15.0 "	100 to 200
7	Middle of third horse-shoe to middle of flat, opposite Jalapa.....	7.9 "	20.5 "	100 to 260
		23.9 "	54.5 "	100 to 228
7-8-9	Air line from summit to Jalapa.....	21.5 "	54.5 "	100 to 254

* The
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Section 8.

Section 9.

NOTES TO PLATE LXXXIV.

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SECTION.	LOCATION.	LENGTH.		Increase by Development.
		By Air Line from Beginning to End of Section.	By Located Line.	
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		23.9 "	54.5 "	100 to 228
7-8-9	Air line from summit to Jalapa.....	21.5 "	54.5 "	100 to 254

* This
surveys, th
ground, an
development
above Jalapa
mapped on
shown.

JALAPA Material appears to be Earth
ashed down from Mountain Slopes.

FERROCARRIL NACIONAL INTEROCEANICO

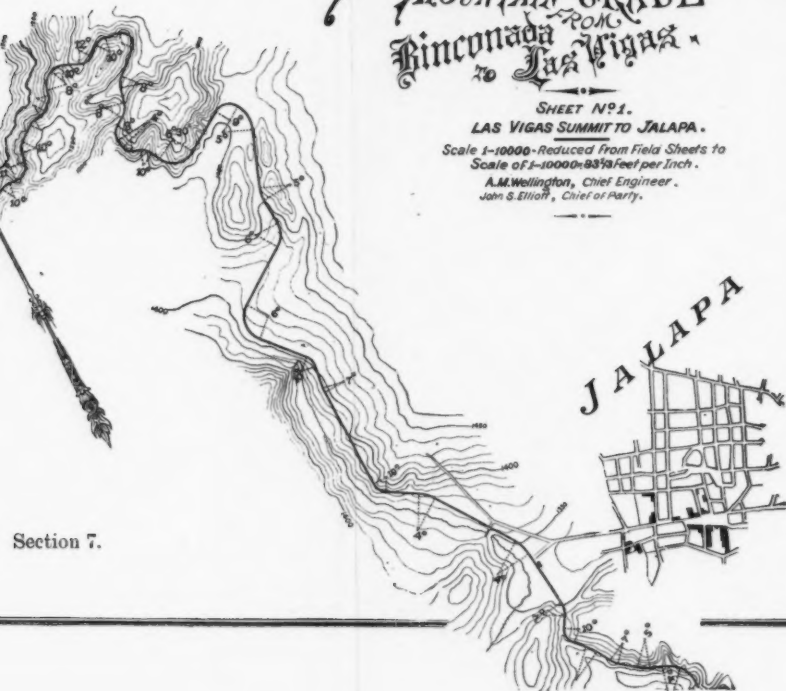
MAP OF THE
PRELIMINARY LOCATED LINE
ON THE
MOUNTAIN GRADE
FROM
Binconada
to Las Vigas.

SHEET No 1.

LAS VIGAS SUMMIT TO JALAPA.

Scale 1-10000-Reduced From Field Sheets to
Scale of 1-10000-83 1/2 Feet per Inch.

A.M. Wellington, Chief Engineer.
John S. Elliott, Chief of Party.



Section 7.

* This Section, 9, as elsewhere noted, was entirely relocated at the very conclusion of surveys, throwing it back from the ragged topography shown, on higher and smoother ground, and somewhat shortening the distance which was gained by an increase of the development on the smoother ground below, where it cost less. The only tunnel on the line above Jalapa was thus taken out, and the quantities much reduced. The line had not been mapped on a small scale, nor even a precise location made, so that no details of it can be shown.

FERRO CARRIL NACIONAL INTEROCEANICO.

From VERA CRUZ via JALAPA to the CITY OF MEXICO and the PACIFIC COAST.

Profile of the PRELIMINARY LOCATED LINE on the
UPPER HALF of the MOUNTAIN GRADE
from JALAPA to LAS VEGAS.

Sections 7, 8 and 9.

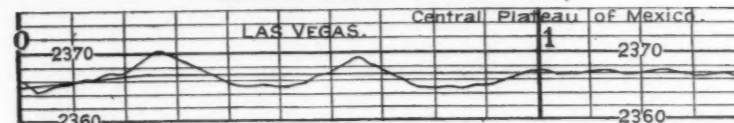
A.M. WELLINGTON, Chief Engineer.
John S. ELLIOTT, Chief of Party, Secs. 7-9.

Levels are an Old Datum reading about 50,000 metres below true Elevation.

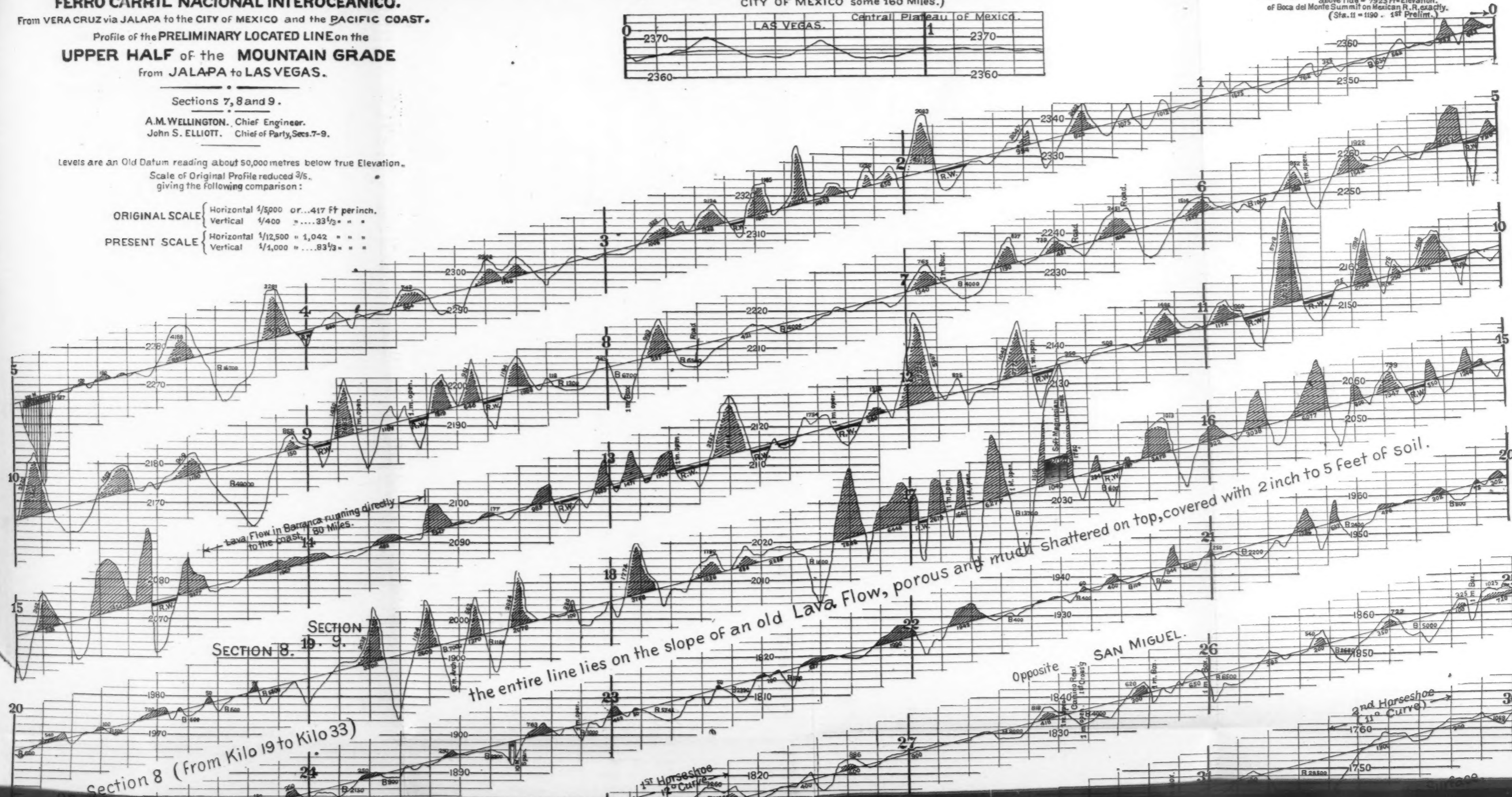
Scale of Original Profile reduced 3/5,
giving the following comparison:

ORIGINAL SCALE { Horizontal 1/5000 or... 417 Ft per inch.
Vertical 1/400 " " " " 33 1/3 " " "
PRESENT SCALE { Horizontal 1/12,500 " " " " 1,042 " " "
Vertical 1/1,000 " " " " 83 1/3 " " "

PROFILE OF PART OF FIRST MILE after reaching the SUMMIT.
(Line continues of this general character for the entire distance to the
CITY OF MEXICO some 160 Miles.)



Beginning of 2 1/2 percent Grade = 2415.0 Metres.
above Tide = 7923 Ft = Elevation.
of Boca del Monte Summit on Mexican R.R. exactly.
(Sta. 11 = 1190 - 1st Prelim.)



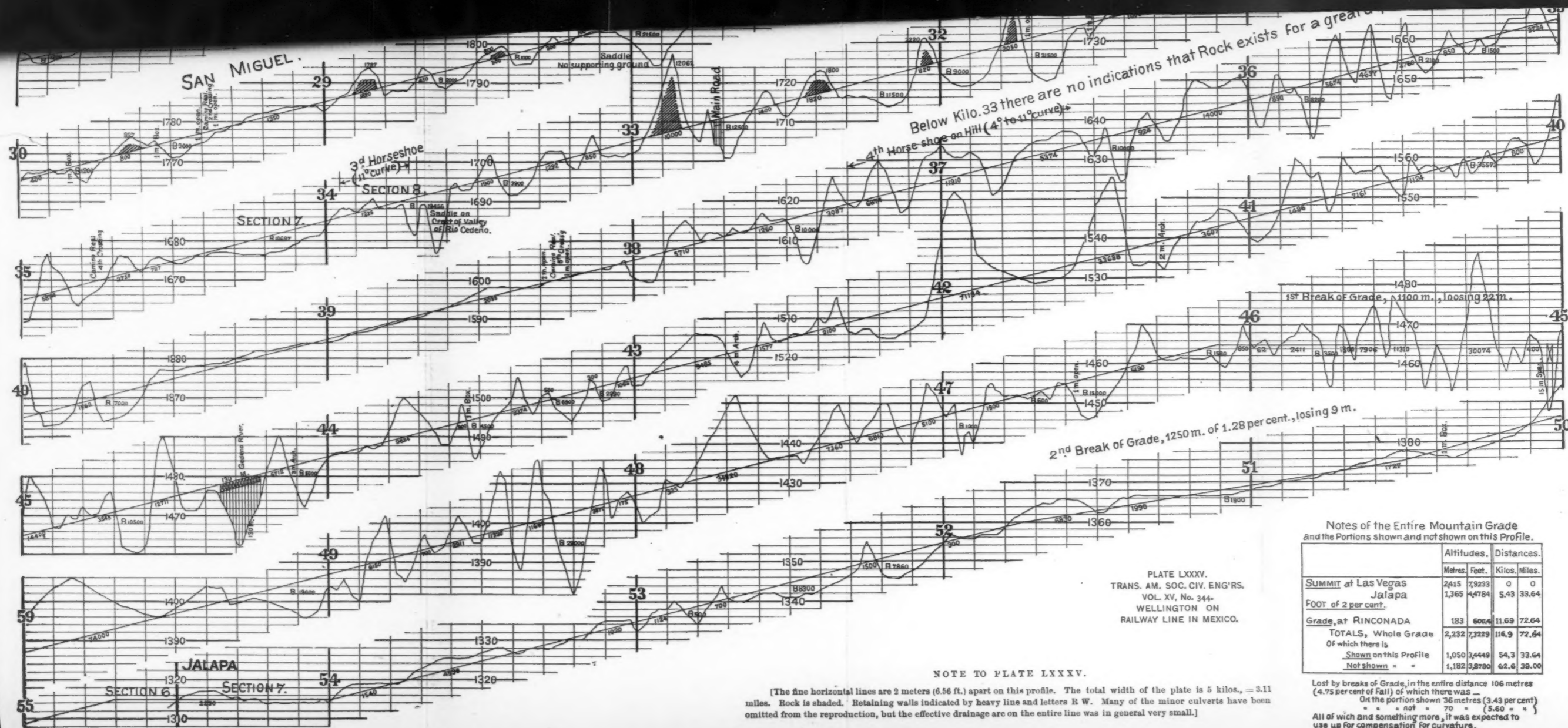


PLATE LXXXV.
TRANS. AM. SOC. CIV. ENG'RS.
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WELLINGTON ON
RAILWAY LINE IN MEXICO.

NOTE TO PLATE LXXXV.

[The fine horizontal lines are 2 meters (6.56 ft.) apart on this profile. The total width of the plate is 5 kilos, = 3.11 miles. Rock is shaded. Retaining walls indicated by heavy line and letters R W. Many of the minor culverts have been omitted from the reproduction, but the effective drainage are on the entire line was in general very small.]

Notes of the Entire Mountain Grade
and the Portions shown and not shown on this Profile.

	Altitudes.		Distances.	
	Metres.	Feet.	Kilos.	Miles.
SUMMIT at Las Vegas	2415	7923	0	0
Jalapa	1365	4478	54.3	33.64
FOOT of 2 per cent.				
Grade, at RINCONADA	183	600	11.69	72.64
TOTALS, Whole Grade	2,232	7,329	116.9	72.64
Of which there is				
Shown on this Profile	1,050	3,444	54.3	33.64
Not shown = "	1,182	3,885	62.6	39.00

Lost by breaks of Grade, in the entire distance 106 metres
(4.75 per cent of Fall) of which there was
On the portion shown 36 metres (3.43 per cent)
" " not " 70 " (5.60 " ")
All of which and something more, it was expected to
use up for compensation for curvatures.

JAN. 1883.

SCALE $\frac{1}{5000} = 416\frac{2}{3}$ FT. PER INCH.

Reduced one fifth scale from the original field sheets on a scale of 10000 or 83 1/3 ft per in.

CONTOURS, 2 METERS (6.56 ft.) APART.

(Line from here ascends
the small stream above.)

(Valley continues of this general character to B, fig. 2.)

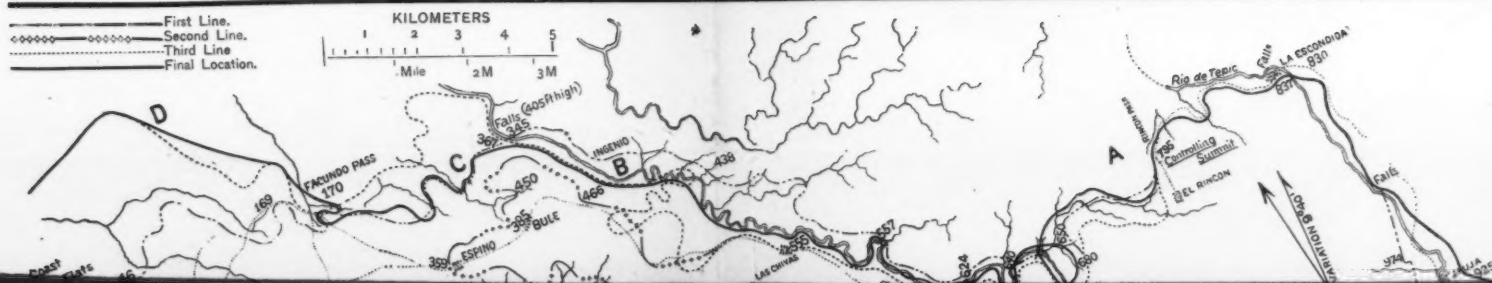


Fig 2.

*Alignment of the Grade descending to the Coast Flats
from Tepic.*

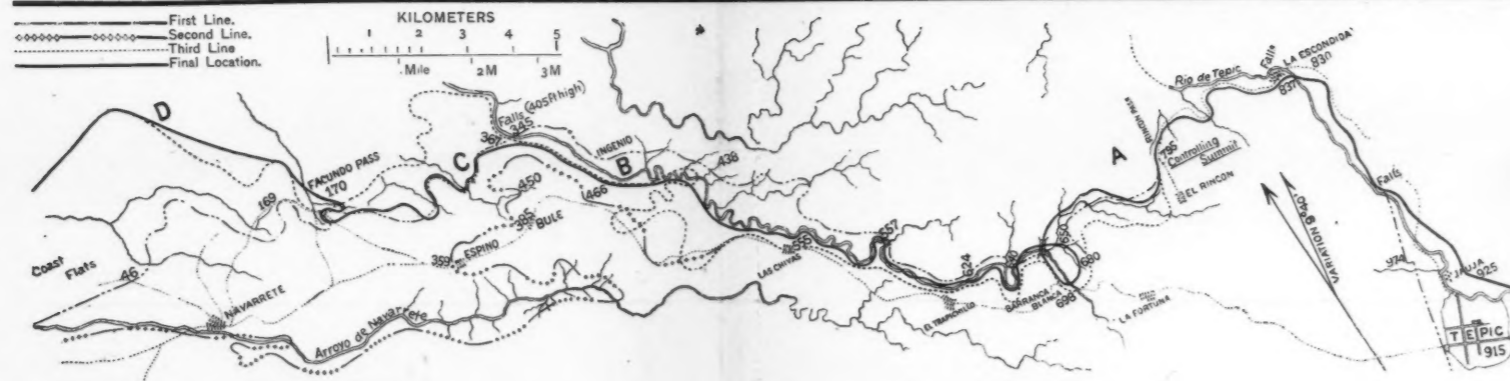
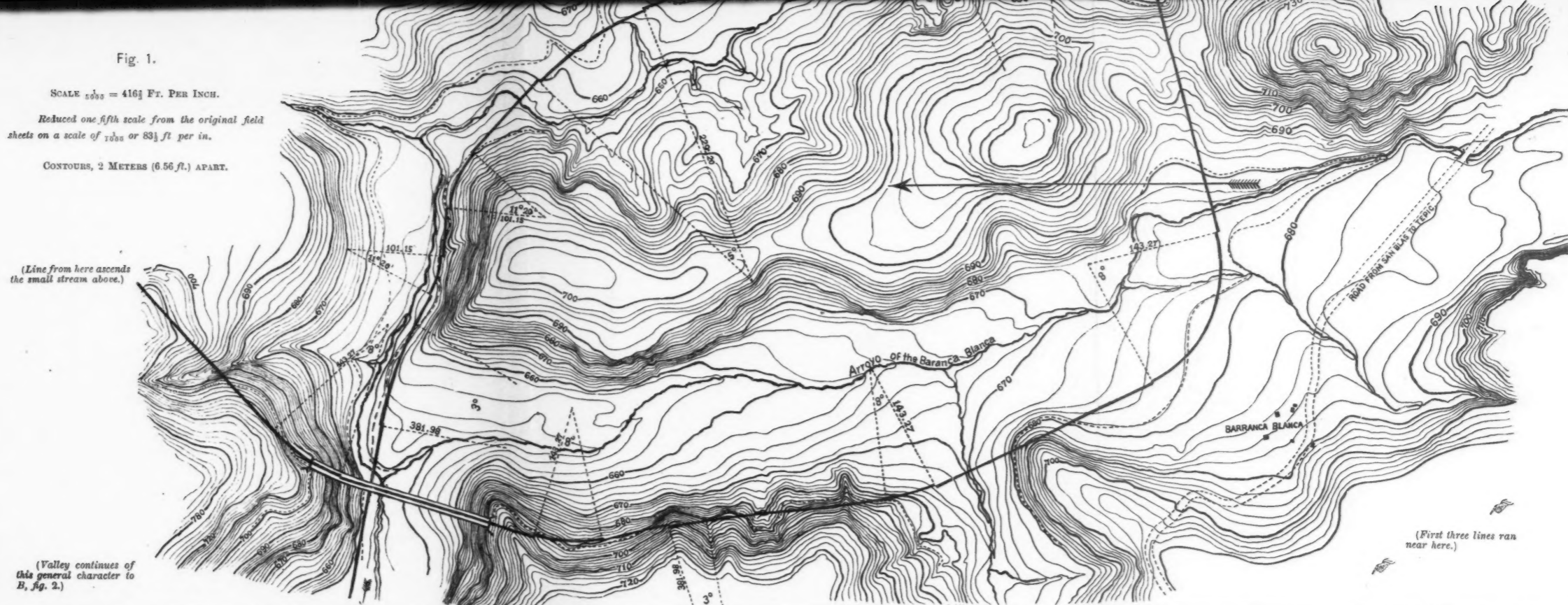
Showing the location of the Spiral and of the Various Routes previously surveyed.

SCALE $\frac{1}{5000} = 416\frac{2}{3}$ FT. PER INCH.

Reduced one fifth scale from the original field sheets on a scale of $\frac{1}{10000}$ or $83\frac{1}{3}$ ft per in.

Reduced one fifth scale from the original field sheets on a scale of 1000 or 83½ ft per in.

CONTOURS, 2 METERS (6.56 ft.) APART.



Alignment of the Grade descending to the Coast Flats from Tepic.

Showing the location of the Spiral and of the Various Routes previously surveyed.

(Black figures give elevation in meters.)



NOTES TO PLATE LXXXVI.

The spiral illustrated is on the lower end of the Pacific Branch of the Mexican Central Railway, on the descent from the city of Tepic to the coast flats, work on which has been recently suspended before construction had reached the spiral. It was located by the writer, who was the late Assistant General Manager in charge of location, the late Mr. Edward Yorke, M. Am. Soc. C. E., Chief Engineer of the Pacific Branch, being in immediate charge of the surveys of the branch. Several efforts were made by various engineers to obtain a practical line, which are distinguished as first, second and third lines in Fig. 2 of Plate LXXXVI, but without any very satisfactory result, until, aided by the knowledge gained in the previous surveys, the idea of the spiral line was conceived and pushed to a successful completion, with a reduction of considerably over half in the estimated quantities of the line.

The spiral line, as finally completed, furnished an instructive example of the extent to which natural difficulties may be avoided by first selecting a place where a portion of the line can lie to good advantage, wherever it may be, and adapting the remainder of the line to it. The conditions, briefly stated, were these:

The town of Tepic is at an elevation of 915 meters, or 3 035 feet, above the sea; and distant only some 17½ miles east therefrom, half of which is a dead flat rising but a few feet above the sea, so that the entire rise would have had to be made on a direct route, within an air-line distance of some nine miles. Descending from Tepic (see Fig. 2), the line first follows the valley of the Tepic River until it diverges therefrom (as it flows in an entirely wrong direction and becomes impracticably rough) and strikes across into the valley of the smaller Ingenio River at the Rincon Pass, marked "controlling summit" on Fig. 2, at an elevation of 2 508 feet (795 meters) above the sea.

Up to this point the descent was on less than a 2 per cent. grade and offered no difficulty, although requiring some heavy work and affording views of great sublimity and beauty over the rugged and abrupt descent to the coast flats.

In descending from this controlling pass into the valley of the Ingenio River (which is the long stream in Fig. 2 which the line follows below the spiral), the usual difficulty was encountered, that the first descent was exceedingly sharp. In an air-line distance of two miles, from the controlling summit to the lower left-hand corner of the spiral in Fig. 1, there was a descent of some 490 feet. Moreover, the valley of the Ingenio, while entirely practicable for a line in or very near to the bed of the stream, had, for many miles below the spiral (to near *B*, Fig. 2) abrupt and rugged banks several hundred feet high, of the same impracticable character as those shown immediately below the spiral bridge, Fig. 1, although below *B* the valley became more tractable.

Under these circumstances, since it was impossible to descend into the bottom of the valley on any practicable grade, and since, unless this were done, the line must be, for a long distance below the spiral afterward adopted, entirely above the immediate slopes of the valley; to avoid the most excessive work, a comparatively light trial grade, 2 per cent., was not unwisely adopted for running the three first lines shown by dotted lines on the map. These lines, otherwise differing from each other greatly, agreed in swinging around the area covered by the spiral and close to the latter, although off the area covered by the map in Fig. 1. To trace them on the map of the spiral, start from near the scale and title and pass thence to the right, then down, and then, at the bottom of the map, to the left, to a point between *A* and *B* on the small scale map, Fig. 2. At this point they were already far above the grade of the spiral bridge, so that they soon left the excessive slopes of the valley and struck comparatively easy work on the narrow ridge lying between the valleys of the two parallel streams shown.

Nevertheless, the work on all three of the lines was excessive, while the low grade required a great amount of otherwise unnecessary development and curvature. Two of these lines were located on paper and profiles made, but no accurate estimates were ever made of them, as the work was very forbidding, involving, in spite of the use of 17-degree curves, a number of tunnels and many retaining walls and small viaducts.

These facts made it clear, if it had not been before, that the attempt to find a line by starting from the summit as a controlling point, and letting it fall thence where it would, must be abandoned, and a line lying in the bottom of the valley as a fixture and worked from at each end; that being the only place where a really economical line could lie for the entire distance down to *C*, Fig. 2, and in a measure down to *D*. The result goes far to prove the utility and necessity of this plan of locating really difficult descents which are measured by thousands instead of hundreds of feet.

A random line in the bed of the stream showed that a 2.6 per cent. grade (137 feet per mile) was the lowest adapted to it, and in assuming the line to be in this position, and extended from each end (*i.e.*, conceiving the line fixed under the bridge in Fig. 1), the ascent thence up the upper small stream was (for the country) mere surface work, and the extraordinarily favorable point for the high crossing (the narrowest for miles) naturally suggested sweeping the line around, through a deep, but narrow, cut into the lower small valley, so as to cross over itself by a high viaduct, and thence ascend to the summit. Above the viaduct it follows up the right slope of the small stream shown just under the title, being on the opposite side from the three previous lines, which chanced also to be somewhat the best side.

It was found on extending the line up to the summit that it left some

spare elevation, and this was properly concentrated within the spiral, in order to make the bridge as low as possible, although doing this had its painful side to the engineer, as the topography readily admitted of an unbroken grade within the spiral and some 50 feet more rise, with even lighter work both within and above the spiral, except that the viaduct would have been higher. Its length and cost would have been very slightly increased, but enough to make it inexpedient.

There was a possibility of a direct line from Tepic to the head of the spiral, following approximately the highway *via* La Fortuna, but it was not deemed worth survey, for these reasons:

First.—It was certain that it could afford no better grade, and but little, if any, difference in curvature, distance, and cost.

Second.—The fine water-power of the Rio de Tepic would have been left at one side, with the mills already on it, and the others which were very likely to be placed there—water-power being very scarce in Mexico.

Third.—There was considerable local traffic from La Escondida and points beyond it to the West, which would be lost.

Fourth.—A dull, uninteresting ride would have been substituted for one of the greatest scenic attractions. A chief dependence for the traffic of the Pacific Branch (and for the main line of the Mexican Central as well) being tourist traffic, and much of the remainder of the line being of great scenic beauty, this alone was deemed a decisive consideration.

The leading dimensions of the spiral and viaduct are as follows:

Length of spiral, 2 637 meters..... = 8 652 feet = 1.64 miles.

(405 + 60 = 669 + 30, with 10-meters station).

Descent in spiral, actual.....53.00 meters = 173.9 feet.

Descent in spiral, on 2.6 grade.....68.56 “

Loss of elongation in do.....15.56 meters.

Utilized as follows:

For curve compensation, 303 degrees (at 0.06
per degree)..... 5.56 meters.

Spare elevation, utilized for a station ground
and water station at south end of spiral..10.00 “

Viaduct: Length, 200 meters..... = 656 feet.

Height, 53 “..... = 173.9 “

The height is above the grade line. Above low water it was some 7 feet more.

The material to be handled was not rock, as might be inferred from the excessive slopes (which are rarely as flat as $1\frac{1}{2}$ to 1), but in part *tepetate*, a kind of volcanic tufa of the hardness and color of very soft-baked clay, found in vast masses in all parts of Mexico, so that it constitutes on many long stretches of railroad nearly all the material moved below a thin soil, and in part *jal*, which consists of thick sand-like deposits of little particles of pumice-stone of the size of a pea or bean, as white as snow; whence the locality derived its name of *barranca blanca*, or white gulch. *Jal* (pronounced *haal*, with strong aspirate), though perhaps the lightest of known materials, holds, like *tepetate*, a very steep slope when protected from wash. Neither *jal* nor *tepetate* exist in any part of the United States or (so far as known) Europe, so that there is no English name for them.

Jal is so abundant in that part of Mexico, that the name of the state, *Jalisco* (the largest state of the republic) is derived from it, and it is certainly in one respect the most extraordinary of known materials. If the whole country were to be gently sunk below the sea, the upper 20 to 200 feet of vast areas of the soil of that state, aggregating thousands of square miles, would rise and float upon the water, carrying in many cases trees, houses and cultivated plantations with it.

The dotted grade-line on Fig. 1 will enable the character of the work to be seen at once. The contours are two meters ($6\frac{1}{2}$ feet) apart, and along the line are minutely accurate. Owing to the excessively steep slopes on or near to the line, it was located with a view to doing most of the grading by large earth (*tepetate*) blasts, which will explain the way in which the line is laid at certain points. Rock crops out above and below the spiral to a considerable extent, being in all cases basaltic lava, with which the whole country is underlaid, but not on the spiral itself, so that its cost was even less per mile (exclusive of the bridge) than the average of the line. The bridge itself was estimated to cost in the neighborhood of \$50 000, which perhaps was too low.

The cost per mile of various sections of the road was estimated to be as follows, at about the usual American prices; the sums given include earth and rock grading and masonry only. There were no tunnels, but some eight or ten small iron bridges or viaducts.

No. of Kilos.	Locality.	Cost per Mile.
10.	From controlling summit to and past the spiral.....	\$14 630
Above Spiral.		
8.	First below Tepic.....	16 680
5.	From Escondida to Rincon Pass.....	58 900

Below Spiral.

11. First below spiral.....	14 700
10. To near <i>B</i> , Fig 2.....	13 120
4. Near <i>B</i> , past <i>C</i>	30 800
7. <i>C</i> past <i>D</i> to limit of map.....	21 800

At the limits of the map, Fig. 2, the line is still some 20 miles from the coast, but only some 75 feet above it, and the difficulties are over. It will be seen that the section, including the spiral and line in the vicinity, is among the cheapest on the descent, where before it had run for many miles over \$120 000 per mile for grading and masonry only. The most costly work was on the three miles passing from one valley to another. The limit of curvature was 17 degrees (foot system--11 degrees 20 minutes metric, for 20-meter chains).

DISCUSSION.

ROBERT MOORE, M. Am. Soc. C. E.—There are one or two questions I should like to ask Mr. Wellington. The conclusions of his paper were certainly very surprising, and did not seem to follow very obviously from the premises. The first question in regard to the author's solution of the problem of overcoming great heights is how anything is saved in distance; in fact, why there is not a loss in distance by those continuations of the line beyond the point of curve. And why there is not a very material loss in the operation of the road by the necessity which that involves of running the train half the time backwards uphill, which, as every one knows, is a very trying method of operating a train. Still further, I would like to know what he would consider the limit of traffic for which he would construct such a road. As I understand him, it is suited only for roads of light traffic. If, therefore, he should construct a road for a traffic of a certain number of trains or tons, and the history of the road should develop a tonnage or train mileage five or ten times that, as very often happens, what would be the condition of the road? Would it not have a location extremely faulty, one which would need to be wholly remodeled, the old alignment being thrown away? I should say generally that I do not know of any more uncertain business than that of estimating upon the future traffic of a railroad, and it seems to me that any system of location which makes a correct estimate of the magnitude of the future business of a road an essential feature in establishing the alignment, rests upon a very uncertain basis. Most of our railroads, even those which are now most heavily taxed, were expected to have a very light business. Time has developed that they have a very heavy one. I think, therefore, that it is safer to locate for a heavy business than it is to locate for a light one, and that a method of location which is based necessarily and essentially upon a light business is a very unsafe one upon which to proceed.

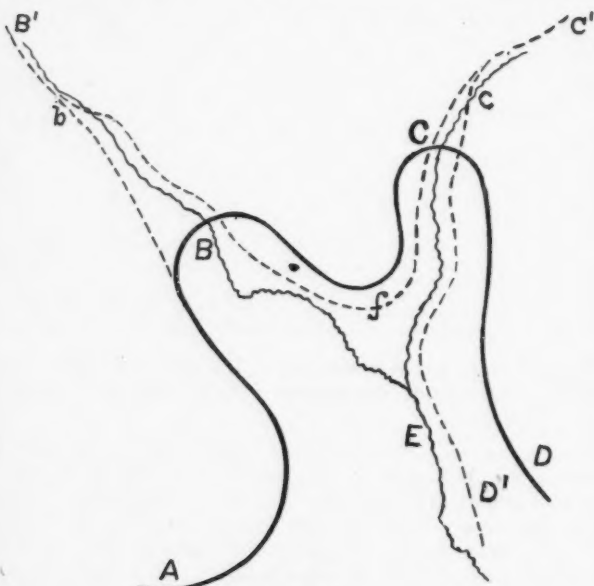
A. M. WELLINGTON, M. Am. Soc. C. E.—I am very glad to have the gentleman raise those points, because they are ones that need of course to be considered. I will touch upon the last one first. I have studied the financial history of railroads a great deal. I could very readily name a great number of roads—I will just mention one that occurs to me now, the West Shore—that have been ruined by starting out with the assumption that they were going to have a magnificent traffic from the first, and that they must have everything strictly first-class for twenty or fifty or more trains a day; but I have yet to hear of the first road that has been ruined by having so much traffic to accommodate that it could not carry it on its own line as originally laid out. Therefore I think that before touching on a question of what limit of traffic can be done over

such a system as I have suggested, the first question is: Is it adapted for a comparatively light traffic, such as all the railways in Colorado and Mexico, and in the Rocky Mountain region generally have to-day, as they had twenty years ago, and as they will continue to have, beyond question, for ten or twenty years to come? It is an almost invariable rule that roads through severely mountainous countries, lines that must be carried over 1 200 or 1 500 feet of rise or more, will continue indefinitely to have a comparatively light traffic. A striking example that occurs to me are the roads in Peru.

The location which is the subject of this paper was made without switch-backs, in conformity to a sort of accepted standard among engineers, that if a location is to be regarded as really good it must be carried on a continuous descent from the summit down, no matter at what cost. The fact that, in Peru, it became necessary to put in switch-backs, is generally regarded as distinctly reducing the credit of the location. Hence, even if I had believed in using the switch-backs as much as I do now, I should have hesitated to use them on my Mexican line, for I should have felt that it would have detracted from the apparent merit of the line, and, both as an engineer and as one acting for a company, I should have felt that I was doing the road an injury. But I think that the contingency suggested by Mr. Moore, of great, but dubious, growth of traffic in the distant future, in such localities where the cost of first construction is very great, is one that is entitled to little weight in the initiation of lines which are very costly at best. The only proper assumption on such roads is that the traffic is going to be light, and that paying the interest on the bonds is going to be difficult, and paying a dividend to the stockholders almost impossible. That is the actual history of at least nine out of ten of such lines, and it is not good financial judgment to consider more than the traffic "in sight," or for eight or ten years ahead. Nevertheless, while the contingency of how large a traffic might be accommodated on such a system is not likely to become important on most mountain lines, I see no reason why a very large traffic cannot be accommodated, fully up to the limit that can be accommodated by a single track elsewhere.

In regard to the question raised by Mr. Moore, as to whether there is not a great loss of time and distance, I reply that the system recommended results in no loss of time, and that there is even a saving of distance. If the gentlemen will look at that section of the switch-back shown in Fig. 3, page 821, they will see that the train as it comes up from the lower grade runs up on the sharper grade at the end of the switch-back and returns backwards. Every foot of that distance on the Y counts as so much effective distance both ways, because the engine uses steam on it both ways, so that the distance on the Y counts twice. The reason may be more fully explained thus: A locomotive is capable of burning a certain amount of coal and no more. A certain amount of

coal represents a certain number of foot-pounds, and a locomotive can generate in an hour or a mile a certain number of foot-pounds and only that. Now, when the locomotive is ascending a certain height with a train, the weight of the train, multiplied by the altitude to be ascended, is the amount of foot-pounds it must do. It can generate a certain number of foot-pounds in an hour. Unless it loses a certain amount of time when it is not generating foot-pounds, it loses no efficiency from the fact of going up a short stretch of track and back again. The fact that there is also a stop is something that must likewise be discarded from the mind, because, by the arrangement of the grades it involves no loss of power like an ordinary stop. If the engine is putting the steam through the cylinders, it is doing just as effective work in lifting the train up the hill on this short stretch as if it were running forward. It is not necessary to shut off the steam to stop the train. The grade does it. It is only necessary to throw over the reverse lever as the engine comes to a stop. Of course, when descending, the power developed not being used up by the resistance of the grade, is stored in the train in the form of velocity. That velocity helps it to go up the next grade, so that there is no reduction of efficiency whatever. On the contrary, there is a



SKETCH 1.

somewhat shorter total length of rails to be gone over. The conditions are entirely different from those which obtain in an ordinary, stop, which involves very serious additions to the virtual grade.

In regard to the final question of Mr. Moore about "running half the time backward;" running "half" the time backward would be a very serious objection indeed; but it is not a necessity, and is not contemplated in the plan that I have suggested. It would only be a very short distance that the engine would run backwards if the line were properly laid out. An example is shown in the accompanying sketch, No. 1. A line descending from *A*, and having to pass the two gulches of the stream *E*, will probably have very costly crossings at *B* and *C*, with sharp curves and probably tunnels in between, and yet find itself high above the stream at *D*. Some one or two such difficult points are very often prohibitory to an otherwise excellent location, or include within a short distance a large part of the total cost of the ascent. At one or two such difficult and governing points of a long ascent, the switch-back enables us to adopt the plan of location *A B¹ C¹ D¹*. By it we save (1) 360 degrees to probably 400 degrees or more of curvature; (2) the cost of the high crossings *B*, *C*; (3) the additional cost in the vicinity of the crossings, tunnels, deep cuts, etc., which the necessity of making the semicircular curves usually involves; (4) the distances *B¹ b* and *C¹ c*, which count twice for climbing the hill for one length of rails; (5) the difference of level *D D¹*, gained by running down into the very bottom of the gulches above; (6) cheaper construction below *E*, due to the lower level of the line; (7) a substantial addition to safety, since a runaway train or car will be stopped by the *Y*'s, if it does not come from too far above. Against this there is only to be charged the disadvantage of running backward over the short stretch *B¹ C¹*, which can be made a slight one either by using locomotives of types best adapted for running backward, or by spending a fraction of the sum elsewhere saved in obtaining an easier curve at *f*, the sketch being one from an actual instance in the writer's practice, but drawn from memory, the line *A B C D* having been that constructed. To sum up, you save lives, cost of construction and elevation. What you lose I do not know.

WILLIAM WATSON, Assoc. Am. Soc. C. E.—Could you give, approximately and very roughly, the amount of traffic that passes from Vera Cruz to Mexico?

MR. WELLINGTON.—From Vera Cruz to Mexico there pass two passenger trains a day on the plateau, one passenger train each way on the heavy grade, and six to eight freight trains. The business of all the roads in Colorado is insignificant. The New York Central road does more business in a week than any piece of road in Colorado does in a year, and it must continue so for a long time to come, because in such regions the universal law is that rates are high. The necessity of some kind of road is

great, because the mining regions must have supplies; but the absolute quantity of the traffic must be very small.

Prof. WATSON.—If the road had been constructed with switch-backs, would the traffic have been under no such limitations? Do you think that your assumptions would have been true on the road from Vera Cruz to Mexico?

Mr. WELLINGTON.—As to the traffic that can be accommodated on a single line, the best illustration is the Fort Wayne and Chicago, I think. That runs the largest traffic of any road in the country on a single track. I cannot say what the traffic is, but they have run in busy times fifty trains a day, and much more on single days. You can divide fifty trains a day into twenty-four times sixty minutes and you will see how often they must go.

Mr. MOORE.—In regard to the comparative immunity from accident claimed by Mr. Wellington for this system of switch-backs, it occurs to me that the chances of casualty entailed by the numerous frogs and automatic switches, every one of which is a source of possible derailment for every train, much more than counterbalance the supposed additional safety in the case of loose trains. And in regard to these, there will be danger of running off the ends of the Y's, or of sharp or possibly fatal collision with a bumping-post, unless the grades and lengths of the switch-backs be adjusted to the greatest speed which can ever be attained by a loose train, and be in consequence quite out of adjustment for the ordinary business of the road.

And as for the particular case which has been referred to, of the Marshall Pass, the work, as I remember it, is nearly all light, and I think that to construct switch-backs into the mountain side at the upper ends of the ravines which he indicates would entail work much heavier than the present line. And this I think would often be the result.

I should say, however, that Mr. Wellington's chief error is one of over-statement. For particular cases no one can deny the great value of the method of location which he proposes, nor the great skill with which he has worked it out; but when he recommends it for general adoption on heavy inclines in preference to the ordinary method of a continuous grade line, he is, I think, stating his case much too strongly.

And I must confess that I do not quite see how, when his train is standing still, and when no steam is being used, there is not a loss of either time or energy, or both.

Mr. WELLINGTON.—The Marshall Pass was mentioned by me only in an illustrative, informal way before I had seen the ground. Now that I have seen it, the character of the topography there is wonderfully favorable for a continuous grade line, the most so of any high summit line I ever saw; but at the Georgetown spiral we have a good example of a point where switch-backs would have been greatly advantageous in

every way. The alleged danger of running off the end of a switch-back may be cured, as in many existing switch-backs, by a short stretch on a continually increasing sharp up-grade, not comfortable for regular use, but sufficient to prevent accident to runaways. As to loss of energy from the stop, if the gentleman will permit me, may I ask if he has ever seen a pendulum swing?

Mr. MOORE.—I believe I have; yes.

Mr. WELLINGTON.—Can you inform me how much loss of energy there is from the stopping of the pendulum?

Mr. MOORE.—Is there any exertion of energy when the train is standing still?

Mr. WELLINGTON.—Up to the very moment that the train starts the engine is working full. It is stopped, not by shutting off the steam, it is stopped by what would not be noticed by a person walking over the track, the rise above the regular grade line. How much rise, at a certain speed, is necessary to destroy the entire velocity of the train and bring it to a stop, can be figured down to the thousandth part of a foot. It is also certain if the energy is absorbed by lifting the train, and the train is afterwards allowed to descend, that there is no loss of energy whatever. Energy can be taken up and stored just as well as it can be used at once. It is not necessary, up to a certain limit, to use energy at the moment that it is exerted to save its loss. It can be stored in the train in the form of velocity, or it can be stored in the train in lifting it up to a higher elevation, as it is when brought to a stop. In regard to the question of the danger of switches, why many of us here in Denver have come by the limited express from New York, and we have run over thousands of switches, and it is done continually all over the country. How many accidents do we hear of from that? Not nearly so many as we do from the breaking in two of a train. The breaking in two of trains is one of the great dangers on grades and it results in some of our most terrible accidents; whereas our train in ascending is ascending at slow speed. It goes through a switch properly laid out with perfect ease, and it is only gross carelessness in setting switches wrong that causes almost all the accidents of that sort that we have. The breaking in two of trains on grades is a constant danger. It is proposed, moreover, to eliminate human fallibility by having the switches operated automatically.

In regard to the question of how much is saved by using a switch-back, it is a new idea to me that it can be cheaper ordinarily, under any circumstances, to put in a curve, which must have a pretty large radius and must therefore be carried with a cut on each side and a high viaduct over the stream, than to run right up into the bed of the stream.

The gentleman said that I laid this down as a general law of location. I beg to correct him. I laid it down as a general law of location for

carrying a light traffic over high inclines, under which I class anything over 1200 or 1500 feet. There are many places where it might be used at lower elevations of 800 or 1500 feet, but I did not lay it down as a general law for anything less than 1500 feet, with light traffic. But there are great numbers of such points all through the country, and there will be more.

J. B. JOHNSON, M. Am. Soc. C. E.—The gentleman has spoken with so much confidence that there was actually no loss of economy, that I think it well to call his attention to the fact that there is a loss, of course, equal to the movement of the train over the portion which is traveled twice, and it is the loss which is entailed in drawing the train over that distance twice on level ground. That is not very much, but that part of it certainly is lost over the power necessary to ascend the same elevation on a continuous two per cent. grade.

Mr. WELLINGTON.—I must beg to differ from the gentleman. I fail to see how there is any loss whatever. A locomotive, to exert a certain number of foot-pounds, must run a certain number of feet to make the ascent in order to generate that energy. If it generate it by running over a short bit of the line and running back again, so much the better. On the contrary, there is a very slight gain—the resistance decreases from the checking of the speed. It is increased, however, by the sudden increase of the speed; so it is about even.

Mr. MOORE.—How about the loss of time? Could you operate a passenger train over this as speedily as you could otherwise?

Mr. WELLINGTON.—Rather more so, for this reason, that you come up with a certain velocity, ten or fifteen miles an hour. You stop for an instant at the end of the switch-back. Then you descend and your descent gives a velocity due to the altitude 3.2 feet (see Fig. 3, page 821), and likewise the amount of separation of the two grades, which is 32 feet, which is 35.2 feet. That velocity represents about thirty-one miles an hour. Starting up the grade at that velocity, which decreases up above to whatever is your minimum speed, makes the average time a little less. At the same time you cannot make much difference in that way, because it is to a great extent a question of how much power the locomotive can generate in a given time as well as a given distance. If you attempt to take the train up any quicker you must cut down the train in proportion.

Prof. JOHNSON.—With a two per cent. grade from a given starting point to a given point at the top, it takes a given distance, a given length of road, to pass from one point to the other. That was the example that was given us. Now, if the switch-back is also a uniform two per cent. grade, then it would certainly take a longer piece of road to reach from the given point at the bottom to the given point at the top, and it will be longer by just the amount of track that is passed over twice; and it was on that

kind of a conception of the problem that I stated there would be a loss of energy equivalent to traveling that additional distance twice. Of course the gentleman is perfectly right in what he says as to a gain in time for generating steam, and it all depends upon the point of view from which we make our estimate of loss or gain. In the sense that you have to travel a longer distance, there is the loss which comes from that additional distance; that is, in passing from the bottom to the top in the two cases there are more foot-pounds of energy used with a switch-back than with a uniform grade, by the amount already specified. This is, however, a matter of small consequence.

Mr. WELLINGTON.—The only difference is the fact that the train starting from that high position gets a sudden start, and has that initial energy to assist it; so that, although there is a loss of distance in one sense, yet if you had those switch-backs every three or four miles you would have a less virtual grade than two per cent., and could increase the actual grade for a short switch in proportion.

Mr. MOORE.—Would you lay out the vertical curves at the ends of your switch-backs for your fast trains or for your slow ones?

Mr. WELLINGTON.—I would lay them out for both, the first part for slow trains, the extreme end for fast.

Mr. MOORE.—What I mean to suggest is that the proper adjustment for a fast train would not be the proper adjustment for a slow train.

Mr. WELLINGTON.—Yes; only the fast train would run a little further out. The effect would be the same. Then a fast train always has a certain excess of power necessarily, so that it would check speed and not run so far off. The great reason why I should say that this plan would be advantageous, would be, (1) that it reduces the first cost very largely in a direct way; and (2) it enables locations to be built on that otherwise could not be built on at all. I have not yet been over the railways of Colorado, but I have no doubt that there are many illustrations in Colorado where they could have kept on very nice smooth ground if they could have used two or three pair of these switch-backs, on which they would have had to run backwards no more than a mile or two in the whole ascent.

A MEMBER.—What is the length of rail used? Would there not be more tons of rail?

Mr. WELLINGTON.—No, we use less, by just exactly the length of that switch-back, because we run up and run back, and that run in both directions counts as so much work done. The engine is using steam in ascending and descending. This question of the modifying effect of stored energy in grades is a subject not discussed in engineering books, which is greatly to be regretted, because it leads to very imperfect treatment of grades. In this case the train is lifted up to bring it to a stop, and that is a permanent gain, because in descending, although it

descends, it acquires a velocity which will lift it back to where it started from without aid from the engine, leaving that work as so much over.

H. H. FILLEY, M. Am. Soc. C. E.—I believe it is nearly universal now to compensate for curves, and it is easy to conceive that by throwing out 360 degrees of curvature as much is gained as lost on the switch-back. As much elevation is gained as is lost with the extra length of rail on the switch-back.

Mr. WELLINGTON.—I do not lose anything.

THE CHAIRMAN, ROBERT B. STANTON, M. Am. Soc. C. E.—May I ask, do you mean in connection with that two per cent. grade that it is a continuous two per cent. grade on your switch-backs from the bottom to the top, taking your point of switch as your turning point on to your other line?

Mr. WELLINGTON.—It would depend altogether on the location of these switch-backs. In the particular instance I have sketched there is a very short distance between switch-backs, say a mile. In that case you have a velocity equivalent to about twenty vertical feet of "head;" you can increase the two per cent. grade by that twenty vertical feet, and still have in that distance a virtual two per cent. grade. It makes no difference what the actual grade of the track is, the train will be floated over it by its stored energy, as if it were going over an actual two per cent. grade without the aid of that energy.

Mr. H. P. TAUSSIG.—The gentleman says the grade is increased. If your limit is two per cent. you are increasing the energy required. I admit that you get the benefit of the increased energy going back off the head block and up the rise beyond. I mean starting from the bottom of the hill up. An engine starting at the foot of a grade will go up that grade a considerable distance, but it generally comes to a stop unless we have a pressure behind it, and in this same case you are increasing your grade right to the very top of your hill, and I do not see how in the world you are going to get over that ground.

Mr. WELLINGTON.—I seem to be doing a great deal of talking, but this is a very important point, and as I say, one not dwelt upon at all in books on engineering. The case stands thus: Starting from the foot of the hill you have a two per cent. ruling grade, which is supposed to be the *de facto* ruling grade. You increase it for a short stretch at the end of the switch-back for the very purpose of bringing your train to a stop, and it does so. But, unlike an ordinary stop, you are then at liberty and required to run backward down the same grade about a train length, which at once gives back your original velocity and a little over, due to the work of the engine. How much over can be precisely determined by the laws of acceleration of velocity, and you are at liberty to increase the grade beyond by just that much and no more. This increase makes no change whatever in the virtual grade, but leaves it two per cent.

Mr. TAUSSIG.—I understand your pendulum doctrine perfectly, but I do not think it works with steam.

Mr. WELLINGTON.—It is not applied to "steam," but to the energy already created from steam. All energy is the same. A certain velocity means a certain amount of energy, and the two are interconvertible indefinitely under proper conditions.

M. COHEN, M. Am. Soc. C. E.—Having had some practical experience in the construction and working of a switch-back railway, I may properly say a word or two on that subject. During the construction of the Baltimore and Ohio Railroad there was occasion at two points to use a temporary road over the top of the tunneled hill during the construction of the tunnel. In one of these cases the ground was difficult and the crossing was made by two switch-backs, or Y's as we termed them, on one side of the hill and five on the other. The maximum grade was six per cent. This was reduced to four per cent. on the alternate stretches, that the locomotives, which were run with head up hill on the heavier grade, should be less liable to lose the water from their very long fire-boxes when running up grade with fire-box in advance.

In this construction the rule was to make the stem of the Y level, but the topography was such that in two of the Y's, with a limiting radius of 300 feet, the line ran off the bank, and, in order to find support for a sufficient length of stem, trestles were resorted to. Here, instead of making the stem level, we were glad to avail of gravity to assist in bringing the train to rest, and the grade was continued to the very end of the Y.

In working that track it would never have suited to start back from the Y at a high rate of speed. The great danger was at the point of the frog, where the adjustment was always difficult owing to the reversed grades and very limited choice of ground. The practice was to come out upon the Y all cautiously and carefully, come to a stand, reverse, and, being sure that the switch was turned, start back with equal care in the opposite direction. We dared not there avail of the arrangement which Mr. Wellington proposes, to use gravity to start the train rapidly from the Y.

With regard to the possibility of working such a track effectively, the completion of the tunnel having been much delayed, the whole traffic of the Baltimore and Ohio Railroad was run over those seven Y's during the winter and spring of 1853, and very successfully. There were no accidents that I remember, except, I think, to a car of road hands who were letting themselves down by the brakes. They carelessly allowed the car to get beyond their control, dashed out on the trestled stem of one of the Y's, and, notwithstanding its upward inclination, were pitched over the end of it and brought up in the ravine below.

C. M. WOODWARD, Assoc. Am. Soc. C. E.—At the risk of coming

back once too often to the same discussion, I would like to say a word upon this matter of loss of energy and length of road. It seems clear to me, and I presume to almost all, that a road would be longer by just the amount of the switch-backs, and that the journey of the locomotive from the bottom to the top is longer on a switch-back track than on one with a continuous two per cent. grade by just the lengths of all the switch-backs.

Now, the amount of steam used, if the steam is used continuously under conditions otherwise equal, depends upon the number of revolutions that the wheels make. The cylinder is filled with steam twice for every rotation of the driver. If therefore the journey of a locomotive is longer on a switch-back track than on a regular track by the length of all the switches, as it clearly is, then the number of revolutions will be greater in exactly the same proportion, and if the steam is not shut off, the amount of steam used would be greater inevitably by just that same proportion. The loss has been spoken of already by some others as that due to the friction of wear up and down a certain length of track. There is no loss, as Mr. Wellington very properly says, supposing it could go up and back again without friction, it would be simply stored energy. Of course, heavier loads could be drawn, but not in proportion to the extra steam used. So far as the cost of the road is concerned, there might be an argument on the other side. Perhaps there would be less sharp curves on the line.

MR. WELLINGTON.—It seems to me that Professor Woodward, instead of opposing anything that I have advanced, is distinctly supporting it. I distinctly took the position that you did gain distance. You make so many revolutions of the drivers, which means so much energy. Now, if you had those switch-backs at certain distances apart, and only two per cent. track in between, I grant that it is not a virtual two per cent. grade, it is about one and three-fourths. I grant, also, that if these come at unequal distances apart, with the same actual grades in between, you have a virtually unequal grade, higher at some points than others, and as the heaviest points govern, of course, there will be a loss—or, rather, no gain—at the other points. But with these inequalities rectified by laying out steeper actual grades for the short stretches, where there is surplus velocity, the more distance you take to get up with the engine the less grade you have, and the less grade you have the more you can haul up. Therefore it is a question of economy and engineering whether you will go a short distance and haul a short train, or go a longer distance and haul a longer train.

MR. MOORE.—There is one point which does not seem to have been brought out quite as clearly as it deserves, and that is, that granting all that Mr. Wellington claims, this method of operating a railroad requires for its success that everything shall be in perfect order, whilst the road

which he proposes, with its automatic switches and nicely adjusted grades, is a delicate machine, and peculiarly liable to disarrangement.

As an illustration of one of the difficulties that may arise in practical working, let us suppose an engine coming up the hill, and loaded with all it can take, at the speed necessary to carry it past the switch and to the end of the Y, finds it necessary to stop at or near the change of grade. The switch, or the track, or the engine, we will say, is out of order, and the train stops just at the point where the grade begins to increase. It will then be compelled to start up this steeper grade without the aid of the energy stored as velocity, which is necessary at this point, and will therefore be unable to go forward at all, as it could do on a continuous grade. Contingencies of this kind will often be likely to happen. You load your train, say, for a two per cent. grade, but at the switch-backs you meet a grade which is much steeper, and up which you cannot go unless you are going at a certain calculated speed. If for any one of many reasons you have a speed less than this you cannot get your train clear of the switch, and must stop. On a road with continuous grades, if you cannot go fast you may go slow. But on one such as Mr. Wellington proposes, if you cannot go fast you cannot go at all.

Again, as I understand Mr. Wellington's theory, he proposes to avoid the loss of energy which must otherwise occur, by taking his train up the hill without at any time shutting off steam. When his train stops on the switch-backs he does not touch the throttle, but instantly reverses his engine, and continues working full steam, at first down a sharp grade, and half the time backwards. But to do all this safely requires not only that the reversing lever be thrown over at the exact moment, which with cylinders full of steam is by no means the easiest thing in the world to do, but requires also that everything—the train, the track, the automatic switches—shall be in perfect order. If this be not the case, both time and energy will be lost.

Amongst the "thousands of switches" mentioned by Mr. Wellington as passed over in safety by the Eastern Members on their way to this Convention from New York, there was, I may safely say, not a single one of the kind which he proposes to use. Not one was automatic, but every one was securely locked in position, and moved only by a switchman.

Nor is the exact adjustment of the grades on the switch-backs to all the varying conditions of traffic, by any means a simple problem. An arrangement of the line and grades which might be just suited to a train of loaded cars would not be correct for a train of empty cars, as in the latter case the distance from the switch to the end of the Y ought to be two or three times as great as in the former. In like manner, if the switch-backs be adjusted for trains going up hill at a speed, say, of ten miles per hour, they will not be correct for trains coming down hill at a speed two or three times as great; or, if adjusted for the down trains,

they will be longer than is necessary for the up trains, and every unnecessary foot means not only a loss of money in first cost, but a loss of time forever afterwards. So that, on the whole, I am inclined to share the feeling to which Mr. Wellington alludes as prevalent amongst railroad engineers and managers, that switch-backs, even such as he proposes, are to be resorted to only where they cannot be avoided, and that they do "distinctly reduce the credit of the location."

Mr. WELLINGTON.—A switch-back system such as I propose has never been used at all, except on a very small scale (at Mauch Chunk), where it worked perfectly for years. Without proper adjustment of grades to them and proper handling of the switches, automatically or otherwise, switch-backs are, I grant, a great nuisance. As to the "thousands of switches" passed over by the Eastern Members, or, I will add, by the gentleman himself, from St. Louis, I am astonished that he should make such an assertion as that he might "safely say" there was not "a single one" of the kind which I propose to use, or that "not one was automatic, but every one was securely locked, and moved only by a switchman." At the gentleman's own city, as in all other large yards where safety and efficiency have become important, interlocking apparatus is alone used, which is "automatic" in exactly the sense that I propose, and it is like going back to the dark ages to hear any one claim or imply that switches "moved only by a switchman" are the safest or best. On the contrary, they are a recognized source of constant danger.

Finally, as to the question of trains sticking on the grade, I am glad the gentleman raised that point, because he has suggested to me something that I had not brought out. He well remarks that in operating the switch-back everything must work well, or you will have trouble. The same is true of any kind of railroad operation. A train is stuck on a continuous grade. It has to go back to the next place where there is an easing up of the grade, and sometimes it is miles away, so that it is very difficult to do that. Supposing now, an entirely improbable supposition, that a train which could be hauled elsewhere on the grade, could not go past the head block of the switch-back at ten miles an hour, what happens? If the conductor were a "live man"—and if he were not, he would soon learn the trick anyway—what he would do would simply be this: He would set the brakes on the rear end of the train, uncouple in the middle, run the front part of the train up on the switch-back, and back on the up track, and leave it there; go back and pick up the rear, put it on behind, and go off on his business; and if he could not get a good start he would see-saw in the hollow of the up track until he did get up the necessary velocity. That is one of the great advantages of that system of laying out a line, that if a train gets stalled, it can in emergency work itself right straight up the grade, and it is

really impossible for a train to get stalled with this system anywhere in the vicinity of the switch-backs.

Mr. F. D. H. LAWLOB, Jun. Am. Soc. C. E.—It would be necessary to have a switchman for each one of these switches, and if we pay them \$500 a year each, that at five per cent. would represent a capital amount of perhaps \$20 000. Suppose we have four or five of those switch-backs, we get a capital amount of \$80 000 or \$100 000. Of course it is simply a question of which would be more economical—to put in a high trestle or deep cuts, or to make an investment in salary for these men. I think in a good many cases the reason our trains have to double is on account of the drivers slipping. Our engines are rated, say, to their full capacity, and it is not a question of the amount of steam they can use, but it is a question whether the load on the drivers is enough to prevent their slipping. Now, where we have a switchman to throw the switches and see that the switch is in good order, and a train comes up, and when it arrives at that switch the drivers are almost slipping, if the grade is increased right at that point the train will have to double. It would be all right, I think, to make the switch-back for that mountain on some grade that we have on the other parts of the road, but if we increase the grade we are slipping the drivers and the train would have to double.

Another gentleman made a remark about the point of the frog, where you go up on an up grade and then you drop back to the point of the frog and then change suddenly and go up again on your switch-back. I think that could be overcome by continuing the down grade beyond the frog for some distance and getting room to put in a vertical curve; descending a little from the point of frog would increase your velocity, of course.

Mr. WELLINGTON.—I have so shown the grade in Fig. 3, page 821. Of course the length of the lead must be on one grade. You cannot run through the switch on one grade going up and on another grade coming back.

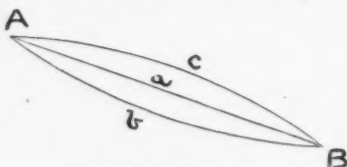
In regard to the capitalized value of switchmen, I have not proposed to use any switchmen, for this reason—that signal engineering has been perfected so much that there is no difficulty whatever in making that thing entirely automatic. Two or three of the interlocking switch companies would take an order to make that apparatus entirely automatic. I have asked an engineer, a Member of this Society and connected with the Pennsylvania Steel Company, about it, and he told me there would be no difficulty whatever. I was cognizant of the fact before, but I asked him to make certain.

In respect to slipping drivers by increase of grade, drivers only slip when the tractive resistance is increased. I have not proposed to do this, but to use the short bit of higher grade to absorb the energy of the train, and bring it to a stop without loss of energy. I am sorry to have to dwell so much on such elementary matters.

Mr. FILLEY.—I would like to ask Mr. Wellington if he proposes to make up the loss of time that it takes a train to run on to the end of the switch-back and stop, by the stored energy, and at the same time increase his grade just above the switch-back to make up for the rise that he has made on the end of the switch-back, both saving his time and increasing his grade at the same time.

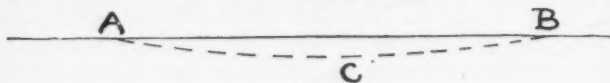
Mr. WELLINGTON.—It is a little difficult to go into that point without taking more time than is proper.

But velocity, mechanically, is not a question of power. It is not a question of so much power and so much velocity. Every one knows



SKETCH 2.

that you can take a body at *A* and let it descend (Sketch 2) to a level at *B* by either of the paths *a*, *b*, *c*, and while the velocity on arriving at *B* will be the same by either path, the time consumed in passing from *A* to *B* will be entirely different, although the amount of work done on the body, as well as its final velocity, will be exactly the same. As the train starts, going up the track beyond the switch-back with a pretty high velocity, it necessarily has a higher average velocity. That higher average velocity does not need any greater exertion of energy. It is simply a question of the path over which a body moves. It gets the body over a given distance with the same energy in a shorter time, just



SKETCH 3.

as a train which would move along the straight grade *AB* (Sketch 3), with a uniform velocity of fifteen miles per hour, will, if there be a slight sag *C*, in the grade, pass over the distance *AB* in less time than *via* the straight grade, although passing both *A* and *B* at the same velocity.

Mr. FILLEY.—I can understand that by giving the train a start from the end of the switch-back it will make up the time it has lost, so that in the next mile, if the grade is kept at the regular maximum, your average speed will be higher; but to increase the grade in this next mile, it seems to me, is to commence losing velocity, and at the end of the mile you will have lost all that was stored up at the end of the switch-back.

Mr. WELLINGTON.—Mr. President, I regret to do so much talking, I assure you, but I am asked questions and have felt bound to defend myself. I will now simply add that average velocity is approximately the mean of the initial and terminal velocity. If you start at twenty-five miles and get to the top at fifteen, your average velocity is twenty miles an hour.

Mr. FILLEY.—Yes, and suppose you increase the grade so that you reduce your velocity within the next three hundred feet beyond the switch-back to your original fifteen miles an hour?

Mr. WELLINGTON.—Mr. President, I could very easily, by taking time, and drawing a few figures, answer the gentleman's question, but it would really be taking too much time. We are discussing too trifling matters. A minute is not an important item, although that minute is on my side. The point of real importance to such lines is not so much to gain a minute or two as to save a dollar or two. I do not want to save some picayune little cost of construction, nor to save this little distance nor that little curvature. The great point is that this plan will in almost all cases save an enormous proportion of first cost and curvature, and give a better line to operate simply by the freedom which it gives in location to pick and choose one's ground. Cheap as is the Mexican line I have described, for example, if I had been at liberty to use a few Y's I should have had a different location. I would not have saved the little sums I could have saved here and there, but I should have kept everywhere on different and far more favorable country, and I should certainly have saved more than half the cost. The chief saving is in the freedom to go where you please.

Prof. WOODWARD.—There is one other point I would like to ask a question about. I think the gentleman stated that the slack in the train would be taken up during the stopping of the train on the switch; that the rear cars would close up on the forward ones and that they would all close up on the locomotive. Am I correct?

Mr. WELLINGTON.—Yes, sir.

Prof. WOODWARD.—Has this been tried?

Mr. WELLINGTON.—That particular plan has never been used on a large scale. I have referred to where it has been used on a small scale.

Prof. WOODWARD.—If it is shown that in spite of the fact that the engine is hard at work, the cars push it up the grade at the end, then I would not have anything to say. But it seems to me that as the steam is not shut off at all, and the engine runs up to the last moment on a slightly increased grade, the train would still be in a state of tension, and that the thumping that would result from an instantaneous reversal of the locomotive on the down track would not leave the people in the rear car insensible of the whole business.

Mr. WELLINGTON.—I refuse to assent to these various points, because, if I may say so, I have been over every one of them many times, and I have not got up here to advance a position that is somewhat contrary to accepted views without being pretty sure of what I am talking about. I regret that an honored professor of engineering should rise here and imply that nothing of the kind can be determined with any degree of precision without being actually tried. For if theory is good for anything, theory should enable us to determine certain things in respect to the effect of energy on the motion of bodies, without trial. If we must continue the discussion from the theoretical point of view, however, we will do so, and I will endeavor to act the part of a professor for the moment.

A train moving up a hill, at a uniform velocity, is in the condition mechanically of a body that is moving through space without any resistance whatever. The resistance of the air, the resistance of the wheels, is exactly balanced, and no more than balanced, by the power generated by the locomotive. Now then, that train, moving along in that condition, is, it is true, in a state of internal tension. The power is applied at the end which destroys the whole resistance. But as it rises it will be seen that the locomotive, the head of the train, is on a little heavier grade than the other. Therefore it is encountering a little heavier resistance and the rear of the train is encountering a little less resistance. It will therefore gradually close up upon, or tend to close up upon the locomotive. As the train comes to the stop, each car moving through space, and having less resistance to overcome than the locomotive, will gradually at the instant of stopping close up towards the locomotive. I have determined that theoretically, but it can be illustrated by a simple experiment. Let anybody take a stick and hang six or eight balls upon it, such as are often used in philosophical apparatus. Each ball may represent a car. Let him slide that back and forward on a straight line. Every time he starts or makes a stop there is a shock going through those balls. Now take those same balls, hung on the same stick, and string them on a cord, and hang the stick so that it can be swung as a pendulum, and you will find those balls will swing as smoothly as possible. There will be no shock between them; only, at the instant of stopping, the rear ball, not being elevated so high as the balls ahead, will communicate a certain amount of energy to the first ball and close up upon it.

Prof. WOODWARD.—I take it that we have had enough of this. I will not say anything.

Prof. WOODWARD.—Subsequently by letter :

I declined to continue the discussion for this reason. Mr. Wellington's illustration of balls on a string swinging under the force of gravity was so *mal apropos* that I did not think it worth the while of the Society

to have me play the professor and expose the fallacy of his reasoning. The lack of analogy between a train where all the force overcoming friction and gravity is in the locomotive, which transmits it down the train by draw-bars and couplings, and a string of balls where the force applied (that of gravity), is not transmitted at all, but is applied separately to each ball, was so obvious, that I felt that all but Mr. Wellington probably saw it.

His assumption that the cars of the train would close up on each other, and all close up on the engine, though the latter were under a full head of steam, even on a 3, 4, 6 or 10 per cent. grade, seems to me extremely wild. If the switches are reasonably suited to long and short trains, *i. e.*, if the increase of grade is gradual, and the engine does not come suddenly to a 20 or 30 per cent. grade, which it could not climb alone, the train would be in a state of tension to the last. It would stop when the engine was no longer able to draw it up so steep a grade.

Then, the train being in tension, and the steam instantly reversed, the locomotive would be sent back, not only with all the force of its enginery, but with the acceleration due to its steeper grade, and the result would be a shock, increasing down the train, much more severe than the engine could possibly give its own train on a level road.

MR. WELLINGTON.—Had my friend, Professor Woodward, ventured to assert upon his feet in the debate what he has added after some weeks' reflection, that he abandoned the discussion at the convention because he was satisfied that every one but myself saw that I was so obviously wrong in my position, I should have been ready to leave that question with the members present; but since he has seen fit since the meeting to raise that unnecessary if not inappropriate question, I will endeavor to show, in a few words, that if the Society did hold the view that Professor Woodward now thinks he thought they held, they were somewhat hasty in reaching it.

Few parallels can be absolutely exact in every detail. If essentially true, that is enough; but, fortunately, my parallel happens to be absolutely exact. The Professor has forgotten that I stated that "at the moment of coming to a stop" the reverse lever was to be thrown over. Interpreting the phrase quoted, I was clearly entitled to assume as understood that the locomotive was to be handled by a locomotive engineer in a proper way, and not by a lunatic, or man unfamiliar with it. Locomotive engineers are not in the habit of throwing over the reverse lever from full gear ahead to full gear back by a single motion of the hand, except in the last extremity. They do it gradually. But however they did it, by the wording of my proposition half the motion was to be complete (and the reverse lever on dead center) when the engine came to a stop. At that instant, therefore, and for a second or two before it, the train is in precisely the mechanical condition pictured by the balls, and it is that final instant which alone concerns us, for it is enough to insure gentleness in closing up.

But even without assuming that the steam was shut off at all before the stop, the Professor is still wrong, if his intention is to assert more than this: that reckless, unnecessary and improper handling of the engine might be made to give a disagreeable shock to the train; a point which, if it is deemed worth making, I am ready to grant, with the addendum that it is a possibility common to every kind of a stop and subsequent start.

Grant that the locomotive comes to a stop with the full steam on, from the effect of the rising grade. The locomotive will then stand on perhaps a 3 or 4 per cent. grade and the rear car on a 2 per cent. Hence the process of taking out the slack will have already begun by some relief of the springs. The reverse lever is then thrown back to or near to dead center—as it needs no words to show that any one in his sober senses would throw it, and not instantly to full gear back. What takes place? Paraphrasing Sir William Hamilton's famous bit of unconscious poetry:

"There is no power, however great,
Can stretch a cord, however fine
Into a horizontal line
That shall be absolutely straight."

We may say that there is no power, however great, can start that train, or any part of it, into rapid motion instantly. Even in closing up slack when starting a train by the power of the locomotive on a level there is no very violent shock, but in this case the locomotive is standing at the steepest part of the grade on a vertical curve, and the locomotive engineer has only to do what every competent man would do instinctively in such circumstances: wait for gravity to start the train before throwing his reverse lever into full gear back—to have the action of natural forces—with which I was justified in assuming that all Members of the Society were entirely familiar—close up the train with the greatest possible gentleness.

The attempted point therefore is, at the best, a distinction without a difference, although I think I have shown conclusively that there is not even a distinction, and I am, perhaps, under the circumstances, justified in adding that the usual process of speaking in haste and repenting at leisure has been reversed in this case by speaking at leisure words which it can be very quickly shown there is reason to repent of.

In closing the discussion I must express my regret that what was after all only a minor feature of the paper—the suggestion that a properly laid out switch-back system was the best for light traffic roads ascending to high elevations—should have occupied so disproportionate a space in the discussion. The extent to which a modification of the modern cable system might be applied with advantage to taking heavy traffic over high summits is, to my mind, a more important and more profitable point for careful attention, although both are important.